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The science curriculum model developed for the American Association for the Advancement of Science (AAAS) as Science - A Process Approach is used to analyze two units of Elementary Science Study (ESS). An "ESS hierarchy" was developed from an analysis of the ESS units, and the resulting behavioral statements were organized into seven levels according to criteria used in Science -A Process Approach. This effort also resulted in the development of an experimental process measure for ESS. Twenty-one teachers administered the revised process measure and content test to their classes during the year 1966-67. The process measure was administered to five children in each of 11 classrooms before they studied the ESS units. This same process measure was again administered toward the end of the year in 16 classrooms to different students also randomly selected. A content test was also administered at this time to these same students. An improvement in performance after studying the ESS units is indicated as measured in terms of transfer to another context and as transfer within the behavioral hierarchy or between learning sets. Gains on the content test were not significant. (BC)

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AN EVALUATION OF ELEMENTARY SCIENCE STUDY AS SCIENCE- A PROCESS APPROACH*

by

Robert B. Nicodemus

September 1968

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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Rockville, Maryland

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ABSTRACT

The science curriculum model developed under the American Association for the Advancement of Science (AAAS) and published by XEROX Corporation as Science- A Process Approach is used to analyze two units of Elementary Science Study (ESS). An evaluation instrument based on the AAAS Process Measure and derived from the ESS analysis was administered to two groups of elementary school students. An improvement in performance after studying the ESS units is indicated. The improvement is measured as transfer to another context and as transfer within the behavioral hierarchy or between learning sets. A content test based on one ESS unit showed little effect of studying the unit and no relation to equivalent levels of the hierarchy. The importance of this analysis and evaluation is discussed with respect to use in the classroom and different levels of behavioral description.

Introduction

This work was begun early in 1966 and completed almost three years later. The initial analysis of two Elementary Science Study units was completed before the summer of 1966.

The "ESS hierarchy" was developed by the analysis of the ESS units through the use of AAAS action words and the organization of the resulting specific behavioral statements into seven levels according to criteria used in "Science-A Process Approach."

This effort, which also resulted in an experimental "process measure for ESS", is indebted to the support and encouragement of Dr. Edwin Kurtz, Professor of Botany, University of Arizona and Dr. Henry Walbesser, Assistant Director, American Association for the Advancement of Science.

In the summer of 1966 ninety-four elementary teachers from the Washington metropolitan area completed a three week full-time program introducing them to new science curricula at the elementary level.* Two units of Elementary Science Study (ESS) were emphasized-Small Things and Kitchen Physics. During this time the "ESS process measure" and content test were given to teachers and a small group of students.. The results were discussed with the teachers who had also been introduced to "Science-A Process Approach."

Twenty-one teachers volunteered to give the revised process measure and content test to their classes during the academic year 1966-67. The process measure was administered to about five children in each of eleven classrooms before they studied one or two ESS units. The process measure was given again toward the end of the year in sixteen classrooms to different individuals also randomly selected. At the end of the year a content test was given to most of the above individuals and also to additional groups who became available through cooperation of teachers. Because of this voluntary situation, comparison of group results is limited. In addition to the analysis, two questions asked in this study are (1) Does the process measure and content test measure any effect of ESS being taught and (2) Does the process instrument represent a valid hierarchy of interdependent behaviors?

The analysis of data and writing were accomplished at intervals following the summer of 1967. I am indebted to Dr. John Wasik, Department of Experimental Statistics, North Carolina State University, for his criticism of the data. Finally I wish to thank Dr. Robert M. Gagné, Professor of education, University of California, Berkeley and Dr. Elizabeth C. Wilson, Director, Department of Supervision and Curriculum Development, Montgomery County Public Schools, for their encouragement and support.

* described in ERIC REPORT ED 013 216 "Cooperative College-School Science Project" by Robert B. Nicodemus, July 1967. 120 pages

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AN ANALYSIS OF ESS SMALL THINGS

A characteristic of many new science programs is the emphasis upon inquiry or investigation rather than information or facts. Although it is readily recognized that inquiry is experienced through subject matter, the important outcomes are identified as attitudes. Science is valued through its power in finding answers but the answers are viewed as a temporary outcome of the main activity of science - inquiry. In the subtle and elusive responses between student and teacher inquiry proves very ephemeral. Until instruments are developed to provide some reliable measures and description of inquiry, it will remain difficult to communicate its strategies.

One beginning point concerns the question of organizing the factual part of the lesson in science taught as inquiry. Two of the more prominent curriculum projects in the United States offer an interesting contrast in answer to this.

In the AAAS project -"Science - A Process Approach" (1) science concepts are presented within the context of what the child does i.e. behavioral objectives. Whether or not the child can exhibit the stated objective is assessed at the end of each exercise by a competency measure. For example, in Observing 1 "Perception of Color" the child should be able to 1. Identify the following colors: yellow, orange, red, purple, blue and green 2. Name the three principal colors - yellow, red, and blue 3. Identify other colors as being like one of the colors yellow, red, and blue. The underlined words are three of the ten action words used to begin every behavioral statement. The three objectives above are restated as a more general component skill - "Identifying and naming the primary and secondary colors." This component skill is only one of thirty-six which are arranged in a hierarchy in which the earlier skills such as in Observing 1 are necessary for the acquisition of later or "higher" skills such as Observing 2 - "Identifying and naming two or more characteristics of an object such as color, size, shape, and texture." The thirty-six component skills constitute the process skill of Observing. The theoretical background and practical use of organizing behaviors into such processes is discussed elsewhere (2). By utilizing a structure based on processes of inquiry, the AAAS materials avoid the dilemma of other projects which attempt to stress inquiry within an organizing structure based on content.

Another well known curriculum project, Elementary Science Study (3), stresses inquiry in science without providing any obvious structure to the content. One of the earlier units "Small Things" (4) unintentionally provides a structure that emphasizes content by a worksheet format. An analysis will show at least twenty-five worksheet questions immediately preceded in "Information for teachers" by an answer which could easily be construed by the teacher as a content objective. For example, "What do you see inside the cell? ______________." "The nucleus, which is located inside the cell, is its major control center." This context makes it very easy for the insecure teacher to have the "answer" right at hand if the child flounders in his inquiry thereby canceling out the ESS "open-ended" approach.

Is there any structure in this unit which would assist a teacher to effectively plan a lesson so as to be able to assist the learner in ways consistent with the ESS philosophy? An answer to this question and the problems it implies was sought by applying the discipline of the AAAS approach to ESS. The first task was to list the sequence of behaviors in the Small Things Unit in terms of the AAAS action words.

Sequence of Behaviors in the Small Things Unit

1. Demonstrating ways to make things look larger
2. Describing characteristics of lenses
3. Demonstrating use of a simple microscope
4. Identifying size of microscope field
5. Demonstrating preparation of a microscope slide
6. Describing size of an object by reference to "hair widths"
7. Identifying Leeuwenhoek as a "great lens maker"
8. Demonstrating use of a compound microscope
9. Identifying reversing of field
10. Identifying effects of magnification on field of view
11. Describing layers of an onion bulb by inference and observation
12. Identifying drawing which looks most like onion skin observed through a microscope
13. Describing "blocks" making up onion skin
14. Naming "little units" cells
15. Describing the interior of cells
16. Identifying effects of three stains on different parts of cell
17. Distinguishing stain to study "little spots" inside onion cells
18. Describing similarities and differences between epithelial and onion bulb cells
19. Demonstrating whether an epithelial or onion bulb cell is bigger
20. Constructing a drawing on onion skin cells from the outside and inside layers of an onion bulb
21. Applying a rule to identify whether a "mystery slide" from an onion bulb came from an inside or outside layer
22. Constructing a drawing of a root tip and describing similarities and differences of onion root tip cells and onion bulb cells
23. Describing similarities and differences of cells from different parts of the root
24. Demonstrating validity of conclusions or "ideas" of cell differences by looking at another slide
25. Describing similarities and differences of cells in an onion leaf
26. Applying a rule to identify where a "mystery slide" came from on the onion
27. Interpreting why cells are different in different parts of the onion
28. Describing cells in an elodea leaf
29. Stating a rule where green cells are found
30. Describing a root system and cells of a root
31. Describing general characteristics of microscopic pond animals
32. Naming animals on basis of movement or shape
33. Naming non-moving objects on slide
34. Describing a paramecium - appearance, behavior (response, eating)
35. Identifying whether or not a paramecium contains cells
36. Describing euglena - it's green plant color and animal movement
37. Applying a rule to classify euglena as a plant or an animal or both

38. Constructing a definition of a plant and animal
39. Describing differences between an amoeba, paramecium and euglena
40. Describing similarity or difference between the outside of an amoeba and the outside of an onion cell
41. Ordering small things on the basis of whether or not they contain cells
42. Describing the arrangement of salt crystals compared to onion cells
43. Applying a rule to predict whether onion cells dissolve in hot water like salt
44. Interpreting why "units" (crystals) stop growing
45. Describing inside of sugar crystals
46. Describing dissolving of iodine crystals
47. Applying a rule to classify crystals as a kind of cell or not a cell
48. Demonstrating use of a balance to measure loss of water
49. Describing cells as containing mostly water
50. Describing living things as being made up of cells
51. Stating a rule that living things have more water in them than non-living things
52. Describing growth of yeast cell (size and geometric progression)
53. Distinguishing whether onion cells and skin cells grow by budding as do yeast cells (use of film loop)
54. Applying a rule to predict how many divisions are required to obtain 130 cells from 10
55. Describing how rapidly yeast cells divide by comparision of average increase per unit time

The behaviors were then analyzed and arranged in a hierarchy analogous to the ordering of objectives in the AAAS materials. (insert Hierarchy of Small Things Behaviors) The first ten behaviors were not included in the hierarchy as they represent more of a set of skills for using a microscope which are, of course, prerequisite to the remaining forty-five. The remaining behavioral objectives are organized under three concept areas:

1. Pond life - identification and naming of characteristics of different organisms
2. Cells - describing characteristics of cells, and
3. Living - describing characteristics of living things

The ordering of behaviors thus facilitates analysis of Small Things. One may identify how a concept such as "life" is supported by behaviors under another concept such as "cells". Also, under one concept one may more readily see the interrelations of its "component skills".

For example, behaviors 27 and 29 form a transition between concepts. Up through 27 the description of cells has been extensively developed and leads into ideas of classification of pond life into plants and animals according to cell characteristics. A second transition between behaviors 43 and 44 identifies a possible weakness since there are no behaviors to help the child interpret why crystals stop growing. Under one concept such as Cells behavior 24 - "demonstrating validity of conclusions or 'ideas' of cell differences by looking at another slide" would require that the child would have acquired some prior behaviors such as -

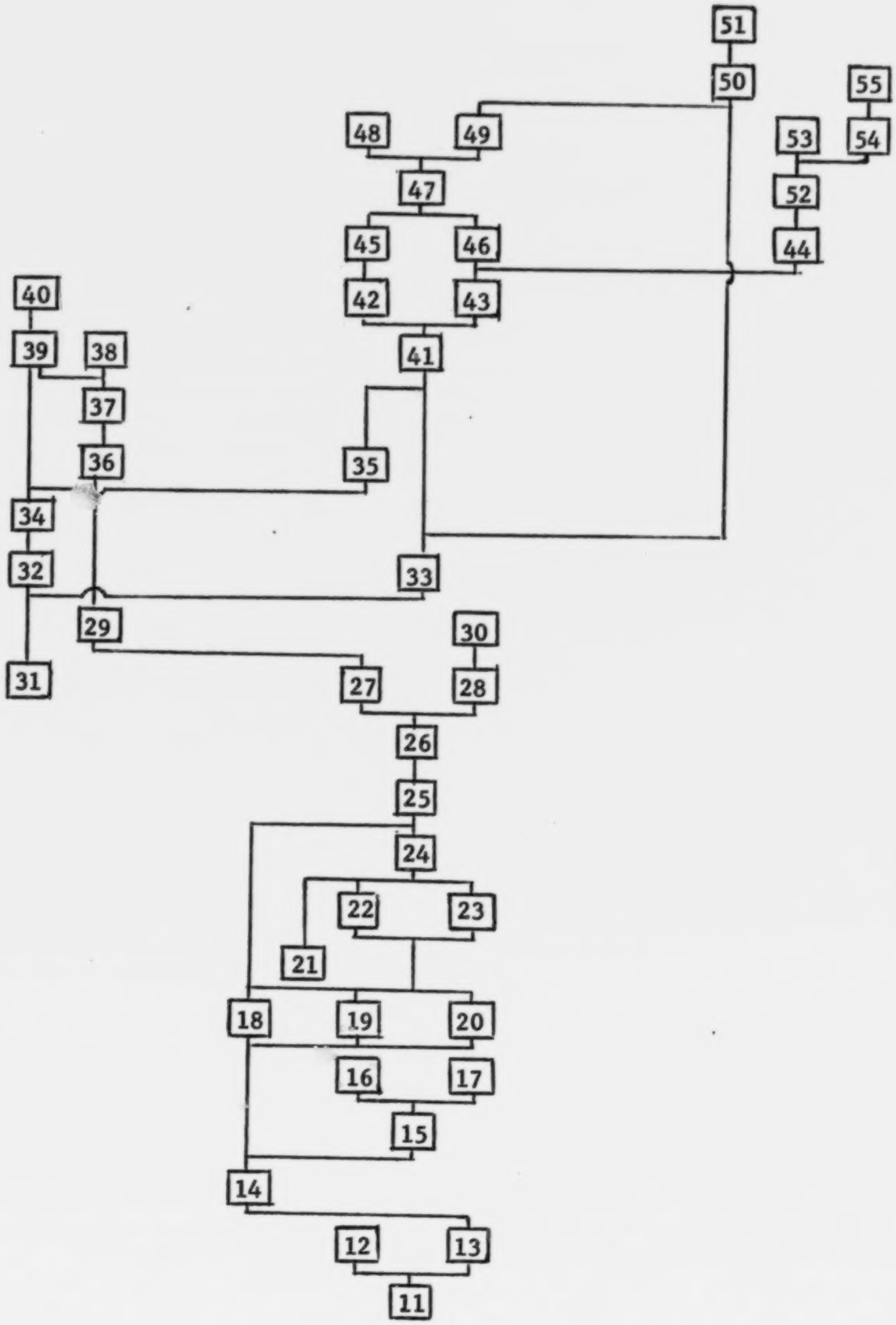
> Describing root protective cells as elliptical in shape and having a waxy outer covering, or
>
> Describing root cells as longer and thinner than bulb cells

Examination of activities preceding behavior 24 reveals very little experience contributing to this knowledge by the "child discovering for himself". The problem is inescapable. Either the child is not necessarily expected to attain certain behaviors or, if he is, it is quite likely that the necessary behaviors will not have been attained.

A second structure other than content was sought in which to organize the behaviors in Small Things. For this purpose the AAAS philosophy was again employed. The "Process Measure" is an instrument which assesses the child's skill in the hierarchy within a slightly different context than originally presented. This situation is similar to studies on "near-transfer" (5) and supports one of the conditions of learning identified by Gagné in which a concept must be generalized through a variety of stimulus situations. (6) To avoid the danger of verbal superficiality, a variety of concrete stimulus situations is essential. Through this repetition, the concept acquires an operational meaning which enables the student to do something. Thus, the test of a concept is where generalization is not limited by physical resemblance.

Hierarchy of Small Things Behaviors

Pond Life **Cells** **Living**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Consequently, the list of small things behaviors were classified into a simpler and general hierarchy more analogous to the ordering of AAAS component skills. After considerable analysis the Small Things behaviors were classified into seven levels going from simple to complex in a logical ordering. The hierarchy also reflects a belief about the psychology of learning in that the child must be able to identify essential features of an objective or solution to a problem before it is presented. The resulting recognition is believed to be an important source of reinforcement. For this reason, the hierarchy begins with the behaviors of identifying and naming. The hierarchy in general has a structure which could be subjected to empirical verification through procedures used by AAAS. It should be mentioned that this is a controversial area. (7) (insert General Hierarchy)

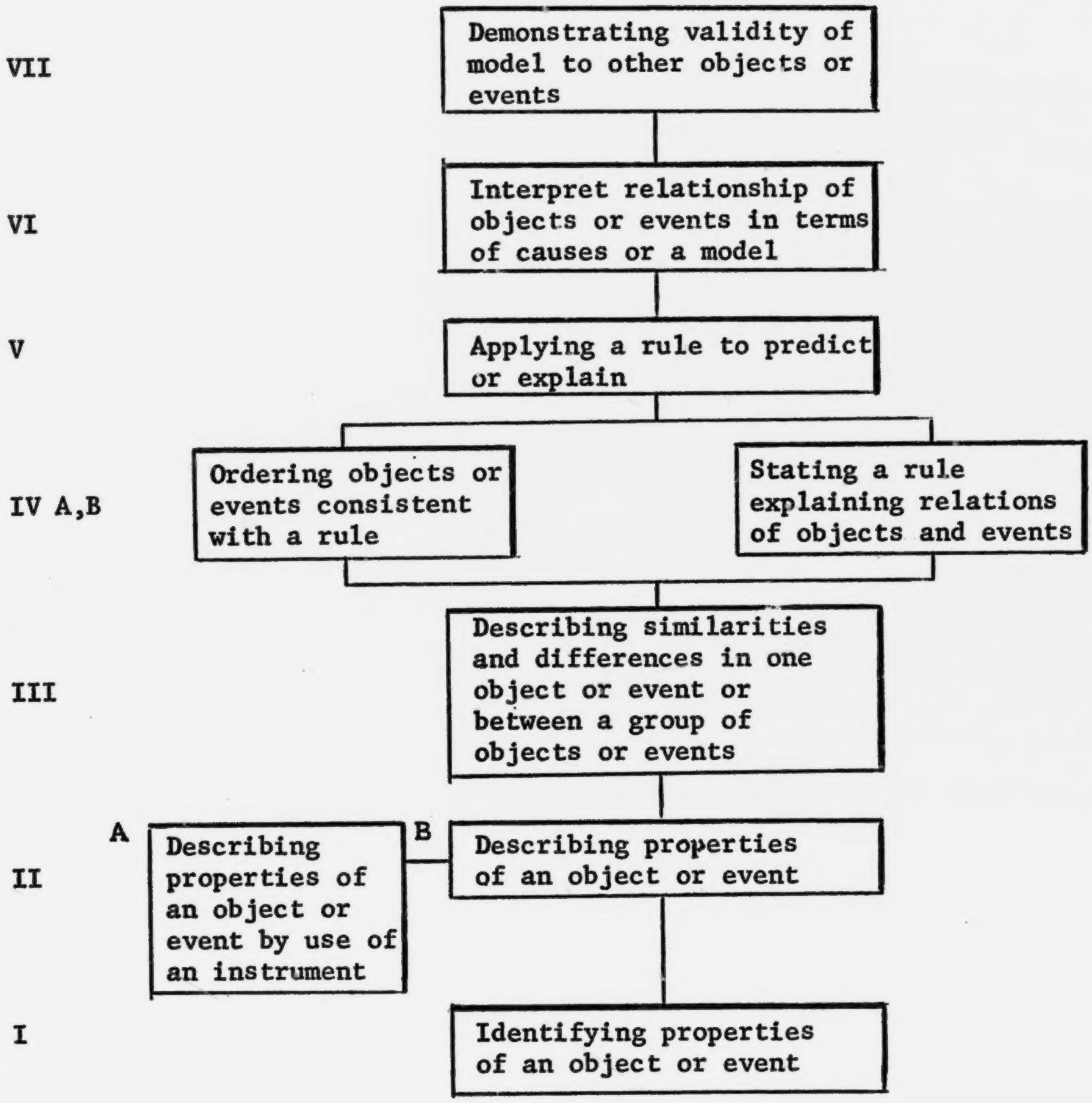
The General Hierarchy could also be used for another level of analysis. For example, behaviors 22 and 23 are classified at level III and behavior 24 at level VII. Unless the learner has ample experience at the intervening four levels-of III, IV, V, VI it would seem less likely he could be successfull in attaining behavior 24.

In summary, the analysis of an ESS unit by the AAAS discipline provides a structure which may be put to a number of uses. The sequential development of content may be examined. The expression of content through behaviors may be generalized into a less specific hierarchy in which the development of more general skills may be studied. This discipline would prove useful in the initial development of a unit. Of greatest value is its use by teachers in planning the teaching of a unit. The child's knowledge and skills may be evaluated in relation to a hierarchy (8) and the instructional program planned to avoid repetition but assuring the possession of behaviors necessary for more complex tasks. The relation of content, behaviors and skills may be readily ascertained and organized in ways useful to the immediate and numerous decisions which constitute a strategy of teaching. (9) Within this total context we may meaningfully talk of learning science as inquiry.

Classification of Behavior in Small Things into the Seven Levels of the General Hierarchy

Hierarchy		Small Things
VII	Demonstrating Validity	24
VI	Interpreting Relationships	27, 44
V	Apply Rule	21, 26, 37, 47, 54
IV	Ordering	29, 41, 43, 44, 51
III	Describe Similarities and Differences	16, 17, 18, 19, 20, 22, 23, 25, 28, 30, 39, 40, 42, 50, 52, 53, 55
II	Describe Properties	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 13, 15, 31, 34, 36, 38, 45, 46, 48, 49, 52, 54
I	Identify, Name	12, 14, 32, 33, 35, 49

General Hierarchy


VII
Demonstrating validity of model to other objects or events
VI
Interpret relationship of objects or events in terms of causes or a model
V
Applying a rule to predict or explain
IV A,B
Ordering objects or events consistent with a rule
Stating a rule explaining relations of objects and events
III
Describing similarities and differences in one object or event or between a group of objects or events
A
B
II
Describing properties of an object or event by use of an instrument
Describing properties of an object or event
I
Identifying properties of an object or event

Summary of Action Words

Identifying	Selecting correct (named) object of a class. Identifying object properties and kinds of changes.
Distinguishing	Identifying objects (events) that are confusable or when two contrasting identifications are involved.
Constructing	Representing (model, drawing) a particular object or set of conditions.
Naming	Supplying the correct name for an object (class) or event.
Ordering	Arranging objects (events) in an order consistent with a rule or category.
Describing	Naming categories or properties of objects and events appropriate to a designated situation.
Stating a Rule	A verbal statement conveying a rule or principle including names of proper classes of objects or events in their correct order.
Applying a Rule	Deriving an answer based on a rule.
Demonstrating	Performing an operation necessary to the application of a rule or principle.
Interpreting	Identify (describe) objects (events) in terms of their consequences (always associated with a rule.)

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(1) Xerox Education Division. Science - A Process Approach: Description of the Program, Parts A, B, and C. New York 1967.

(2) Gagné, Robert M. "Elementary Science: A New Scheme of Instruction" SCIENCE Vol. 151, No. 3706, January 7, 1966. pp. 49-53

(3) ESS is now part of the Educational Development Center.

(4) Teachers Guide for Small Things. Experimental Edition published for ESS by Houghton Mifflin Co. Boston 1965. Although this article is based on the experimental edition, there has been very little change in the final edition published by Webster Division of McGraw Hill.

(5) For a recent bibliography on this see: Worthen, Blair "Discovery and Expository Task Presentation in Elementary Mathematics". Journal of Educational Psychology Monograph Vol. 59, No. 1 part 2 February 1968.

(6) Gagné, Robert M. The Conditions of Learning. Holt, Rinehart and Winston, New York 1965.

(7) See for example the letter in SCIENCE Vol. 151, March 4, 1966 p. 1033.

(8) Walbesser, H. H. and Carter, H. "Some Methodological Considerations of Curriculum Evaluation Research" Educational Leadership, Vol. 26, No. 1, October 1968. pp. 53-64.

(9) For a discussion of interaction analysis see Mirrors for Behavior: An Anthology of Classroom Observation Instruments. Ed. by A. Simon, E. G. Boyer. Research for Better Schools Inc., Philadelphia, Pennsylvania 1967.

II Teacher Adoption of "Objectives"

Because teaching is usually directed toward some goal, the content or factual part of the Small Things unit may be given more priority than the authors intended. This outcome is a function of the relationship of worksheet questions to information for teachers and the absence of unambiguious guidelines which the teacher may use for evaluation. In the "open-ended" approach", any outcome may be valid but the teacher must have some basis to evaluate where the individual student is and on this basis determine how the learning situation may be structured to increase the probability of achieving desired outcomes. In the open-ended approach represented by ESS there is a dichotomy inherent between the one goal of accepting what the child experiences and at the same time encourage accuracy and precision in observation and description.

To determine how teachers view relation between content objectives and inquiry teaching, two questionnaires were given. At the end of the 1966 summer training session the "Analysis of Teacher Activity" was responded to by all participants. Their responses demonstrated that the majority differentiated the one model of inquiry teaching represented.

In the spring of 1967, a second questionnaire was given to the twenty-one teachers who were participating in the evaluation phase of the project. Items on the "Opinion Questionnaire on Objectives" were derived from the analysis titled "Assumed Small Things Objectives" of the worksheet questions and information for teachers. The results show that the majority of teachers accepted the majority of twenty-five factual statements as valid objectives of the unit. It was interesting to note that the only dissention came from the master teacher from Baltimore who had considerable experience with Elementary Science Study. He stated-

> "I cannot accept three category answers on this for the following reasons: (1) Those I noted A were in most cases simply teacher background information which from the ESS point of view may or may not be deamed understandable to pupils, depending on many things. 2. I do not like them stated as objectives...not unless the child was able to couch his belief in words more carefully chosen in some cases, evidence cited generally, or sources provided. 3. Many I listed as A could well be B depending on mode of learning, provision for learning in greater depth, perceptual level of fifth grade, etc."

A second part of the 1967 questionnaire "Opinion Questionnaire on Classroom Activity" support the conclusion that teachers understand the idea of inquiry teaching. Of the twelve items four are associated with expository teaching. Out of twenty four teachers an average of less than one checked items seven, eight, nine, and twelve. The majority of responses under item twelve reflects some ambiguity about not directing a child but encouraging him to seek answers in many ways. This objective is definitely one ESS encourages but fails to point out the differences in directing a student by the questions you ask. Items four and five are ambiguous to a lesser extent. Descriptions of inquiry teaching in some other projects discourage the sharing of findings or answers between students. It is felt that each individual child should discover "for himself". ESS has a much more social outlook and encourages the children to examine the basis for differences in observations. The child would become aware of the fact that the differences are attributed both to differences in individuals and differences in procedures. This naturally leads ESS in encouraging statement twelve which also had a relatively low response level. The relation between items four and twelve is to be expected. Item five is also related to the above. Since ESS encourages the use of many methods and the sharing of results, it would be expected that for every answer selected there would be some rejected. However, ESS leads the teacher to recognize the "right" is a relative thing, as in item ten, and all answers are tentative. Therefore the idea of discard may seem a strong statement when these answers may be later revived on further evidence.

Analysis of Teacher Activity*

Two teachers were observed for fifteen minutes and the following forms completed by the observers. If these observations were fairly characteristic of the classroom, could you make any generalizations about each teacher's philosophy of classroom management: How successful would you think each one is in creating an atmosphere of inquiry?

Number of Times Observed						
Teacher A			Teacher B			
often	seldom	none	often	seldom	none	Behavior
✓			✓			a. Teacher encourages student to try his idea.
✓				✓		b. Teacher expresses agreement or disagreement with student's idea before student tries the idea.
✓					✓	c. Teacher tells the student what to look for before activity begins.
✓				✓		d. Teacher leads students to the desired conclusions based on one experience.
	✓		✓			e. Teacher responds to students' explanation with non-committal comment such as "How do you know?"
✓				✓		f. Teacher agrees or disagrees with student explanation.
	✓		✓			g. Teacher guides student observation or thinking by using "Don't fit" situations.
✓				✓		h. Teacher performs the activity.
✓			✓			i. Teacher paces the activity to match student progress.
✓			✓			j. Teacher poses questions to secure specific answers.
✓			✓			k. Teacher poses questions to secure ideas from students.
	✓		✓			l. Teacher probes basis for inappropriate responses.
✓			✓			m. Teacher accepts responses of children and when appropriate probes child to extend responses.

---

* Adapted from Teaching Observation check list (unpublished), "Role of Teacher Atmosphere of Inquiry," Science - A Process Approach. Commission on Science Education of the American Association for the Advancement of Science.

Representative Responses of Teachers to "Analysis of Teacher Activity"

Of the two teaching characteristics described above, I would think Teacher A would be the better science teacher. He or she seems to encourage the student to satisfy his curiosity on certain matters rather than giving him an evasive answer. He seems to channel questions to instill an inquiring manner. Teacher A also instructs the student by giving him hints on what to look for.

Teacher B's students should be working in a good atmosphere of inquiry since the teacher has not designated a fixed answer for everything nor has a limit been set as to the amount of thinking and conclusion.

Teacher A seems more content than process oriented, has a somewhat structured program, assumes more of the leadership to achieve getting content across. I think both A and B might successfully create an atmosphere of inquiry, but B probably will do it more effectively and more thoroughly.

This is a fantastic amount of information to be gleaned in 15 minutes. But I suppose it shows that Teacher A has a more teacher-centered classroom rather than child-centered. Teacher B turns the spotlight on the child's own activity and reasoning ability, leading him on, encouraging, probing, etc. He would, therefore, be more successful in creating an atmosphere of inquiry.

Teacher A probably feels that because she is carrying on most of the action and/or talking that she is teaching....Has not yet realized that there is no teaching without learning. Uses much effort but weak in management and skills as well as knowledge of how people learn. Teacher B is the better teacher -- she guides the children, makes suggestions, etc. This is a child-centered room....This teacher's philosophy is that what the child discovers for himself is more meaningful and satisfying than being told what questions he should wonder about and what the answers are, as Teacher A did. Teacher B's class is probably more highly motivated, more industrious and has fewer discipline problems than A. B has provided for individual differences.

Teacher A seems to like a more structured situation in the classroom. He leads the student to form his own conclusions;

however, he allows no one to become misled by doing their own thinking. He sets specific goals and aims to accomplish them with no time wasting by coming up with incorrect conclusions. He keeps the class under control by doing most of the activities himself. This also insures him of appropriate results with no deviation from the desired ones. His activities seem to be for the sake of demonstration of principles rather than for experimentation and discovery of principles. Teacher B, however, seems to promote an atmosphere of discovery. The class is probably less regimented. There seems to be more opportunity to discuss results of activities and for the children to draw their own conclusions. The classroom of Teacher B is probably a far better atmosphere for inquiry. After a while students of Teacher A probably discover that he will tell them the answer presently so they might as well wait to hear it. They will be more reluctant to express their ideas if the teacher disapproves of their responses. Eventually they might become a passive audience merely listening to a dialogue between the teachers and a couple of the "smart kids".

Opinion Questionnaire on Objectives*

Please place one of the following three letters corresponding to your opinion of the statements below:

A. An objective of the Small Things Unit that may be attained by most fifth graders

B. An objective of the Small Things Unit that will not be attained by many fifth graders

C. Not an objective of the Small Things Unit but an outcome that may be observed

N=21

A	B	C	In the Small Things Unit the child learns that:
21	0	0	1. There are much smaller levels of organization than can be seen with the un-aided eye.
21	0	0	2. Living things are made of fundamental units called cells.
14	1	6	3. Living things possess some characteristics in common with non-living things.
16	0	5	4. Staining cells helps to see them better.
20	0	1	5. Cells from the same organism will differ in size and shape.
16	2	3	6. Magnification decreases the field of view.
14	2	5	7. Clear curved objects make things look bigger or smaller.
10	8	3	8. Thickness of a cell wall varies with the location of the cell.
16	2	2	9. The nucleus is the major control center of the cell.
7	7	7	10. The shape of a cell is related to its function.
9	7	5	11. The shape of a cell is related to its location.
19	2	0	12. Plant and animal cells are similar in some ways.
13	3	5	13. Plant cells have a thick non-living cell wall.

A	B	C	
17	0	4	14. Plants need a green substance to make food.
12	3	6	15. Cells of an onion root are longer and thinner than cells in the onion bulb.
13	0	7	16. Root cells are specialized for absorption of water and minerals and for their transport to leaves.
14	1	6	17. Roots håve specialized outer cells called root hairs.
13	6	2	18. Protozoa are very complex single cells.
8	5	8	19. Euglena are attracted to light.
4	9	8	20. Cells that store food may have starch granules.
11	7	3	21. Only things which have cells are living or were once alive
18	0	3	22. Living things are made of cells or materials produced by cells.
7	6	6	23. Cells do not dissolve.
6	6	9	24. Living things are made of more complex parts than non-living things.
5	4	11	25. Living things have more water in them than non-living things.

* A fact, understanding or ability intended that the student will achieve as a result of a planned experience.

Opinion Questionnaire on Classroom Activity

In classrooms studying Elementary Science Study units which of the following behaviors would you expect to observe more readily? Check those behaviors you would expect to be more common with an ESS unit such as Small Things, Mealworms or Kitchen Physics. Leave blank those behaviors you would not expect to observe as readily.

Number of teachers checking		
22	1.	The child learns how to measure with increasing accuracy.
22	2.	The child evaluates evidence to confirm or revise generalizations.
21	3.	The child tolerates more uncertainty as a result of basing conclusions on his own evidence rather than an outside authority.
7	4.	The child bases generalizations only on his own results.
3	5.	The child selects from a number of possible answers just one right answer and discards the rest.
21	6.	The child asks questions in a way that he is more able to answer himself.
0	7.	The child relies more on the teacher in classroom activity.
7	8.	The teacher guides the child toward objectives that are determined before the lesson.
1	9.	The teacher readily gives explanations and answers to the class.
21	10.	The teacher does not grade responses as right or wrong.
24	11.	The teacher lets the child see the need for keeping records rather than telling him to do so.
14	12.	The teacher suggests as few methods as possible for the children to use in acquiring specific knowledge.

"Assumed" Small Things Objectives

Relation of Worksheet Questions to Information for Teachers in the Small Things Teachers Guide

Worksheet Questions	Information for Teachers
1. Are the blocks all exactly the same size? Are they all exactly the same shape? p.37	1. The difference between length and width may have to be pointed out to some of the children. p.32 These cells are about ½ hair width and 2 hair widths long. p.33
2. What would be a good name for these blocks? p.37 "These pores or cells were not very deep, but consisted of a great many little boxes." (Quotation from Hooke p.39) Even today we call the little units you have seen in the onion skin _ _ _ _ _. p.39	2. Let the children come upon it independently. It is included in the quotation from Robert Hooke. p.33
3. What do you see inside the cell? p.44	3. The nucleus, which is located inside the cell, is its major control center. p.43
4. If you were studying just the little spots which you see inside some of the onion cells, which stain would you use? p.45	4. Methylene blue and Lugol's iodine stain the cell wall and nucleus darker than the rest of the cell. p.43
5. How are epithelial cells like onion bulb cells? p.50	5. Both types of cells have a nucleus. Cell membranes are the living outer boundaries of plant and animal cells. In plants such living membranes are usually closely surrounded by cell walls and cannot be

	distinguished easily. p.48
6. How are they different from onion bulb cells? p.50	6. The onion cells are thicker.. ..have thick non-living cell walls (as most plant cells); the animal cells do not. p.48
7. If you had a mystery slide from an onion bulb, how could you tell if the specimen came from an outside or an inside layer? p.56	7. The cells in the inner layers of the bulb are increasingly smaller toward the center than those on the outside of the bulb. p.53
8. Describe how the cells of the root tip are like or different from the cells you looked at from the onion bulb. p.56	8. These cells are longer and thinner than the cells of an onion bulb. The cells of the bulb are specialized for the storage of food. p.53
9. Are the cells at the tip of the root just like the cells higher up in the root? p.56	9. ...we first encounter the root's protective cells. Their elliptical shape and a waxy outer covering facilitates their function. p.54
10. Are these cells different in any one way from all the other cells you have seen? p.57	10. The green coloring...is necessary for absorbing light energy to make food. Leaf cells...are smaller and more square-shaped than the bulb cells. p.53
11. Why do you suppose the cells are different in different parts of the onion? p.57	11. In the onion, then, there is a variety of cell types, each one of which is specialized for its own function. p.53
12. Are all the cells of this root the same? p.58	12. ...vividly portrays the difference of cell structure and function in an organism. The outer protective cells, the root hairs, the elongated inner tubular cells, the expendable root tip cells, and the active growing portion called the meristems are visible....the root hairs protruding from the main trunk of the root are

	absorbing moisture and nourishment... p.54
13. If you have seen a paramecium when you thought it was going backwards, what do you think made it back up? p.81	13. The fact that paramecia bump into things tends to indicate that they cannot see. p. 73
14. What would you guess the paramecium eats? p. 81	14. Paramecium eat bacteria and small particles. p.74
15. Can you see cells in paramecium? p.81	15. "Protozoa" is a name given to one-celled animals. p.63 A protozoan...is a remarkably complex single cell. p.64 A rotifer...is smaller than some of the one-celled protozoa. p.73 As one food vacuole becomes filled, it moves to another part of the cell... p.74
16. Could it be that euglena is not either a plant or an animal but in some ways is like both? p.83	16. Euglena also collects in light patches. p.71 Thus, the organism is somewhat like a plant, since animals do not contain chlorophyll. However, its other structures and habits are clearly animals. For these reasons, the euglena is considered as a borderline organism, part plant and part animal. p.74
17. How does your amoeba move? p.85	17. Locomotion is provided by the pseudopods (false feet), which bulge out and carry the organism along. p.75
18. Were there some materials in which you found units that looked like cells, but which may not be cells? p.95	18. Some of the children will think that the grains of chalk, dust and sugar are cells...it would be a good idea to ask why...In the discussion we would hope that the idea of a cell wall or a dark dot in the center would be brought up. p.90

19. Did you find more cells in living or in non-living things? p.95	19. The hoped-for generalization from this investigation is that the only things which have cells are either living or were once alive. If this generalization does not arise spontaneously, do not make it yourself for the children. p.90
20. Do you think that the units you saw in salt are cells? p.95	20. The matter of whether salt, sugar or other crystals are cellular because they look like cells is an important point. It suggests that one cannot make a decision on this point by appearance alone. It is necessary to make a variety of tests before one can be certain (In the case of salt and sugar, they both dissolve in water; chalk dust will bubble and disappear in vinegar. Neither onion cells nor hamburger meat cells will disappear in either). p.91
21. Do you think that the units you saw in salt are cells? p.95	21. Wood, sawdust, and paper are made from materials which once were living and therefore were made of cells; whether a cellular structure is still visible or not depends on the state of the materials. Sugar does not have any cell structure largely because it has been processed. Cells are not found in eggs because an egg is one large cell. p.91
22. What substance had the greatest amount of water? p.119	22. ...they are ready to be introduced to the problem of whether there is water in various materials...you might well begin the discussion by asking what the children think cells are made of...one way to elicit this idea is to..... p.108

23. How much of it was water? p.119	23. ...almost all cellular materials are 70 to 80 percent water and will loose weight accordingly as the water evaporates. p.110
24. Did all the materials from living things have a high or low percentage of water...what does this investigation tell you about living and non-living things? p.119	24. ...one way to determine whether a small unit of material is living or non-living, that is, whether it is cellular or non-cellular, is to dry a sample to find out the percentage of water it contains. Since we know that cellular material contains a high percentage of water, this can be used as a clue in determining whether the material may be living or non-living. p. 111
25. Do you think onion cells and skin cells increase in number as yeast cells do by budding? Why or why not? p.126	25. Hopefully, they will suggest "What about taking pictures?" ...This film loop shows the yeast cells in the process of cell division. It will be noted that each cell divides by budding off a smaller cell rather than by equal division, but each cell still changes into two new individuals and these divide again in their turn. Yeast is one of the few organisms which reproduce by the budding process. p.123

III Preliminary Analysis of Kitchen Physics

.Time to Empty

1. Identifying water emptying from a bottle p.8
2. Stating rule relating emptying time and size of hole in container p.10
3. Demonstrating emptying time for five different size holes p.11
4. Identifying variation in results and average values p.12
5. Applying a rule to predict emptying time from hypothetical size holes p.12
6. Ordering results in a chart p.12
7. Applying a rule to predict size of hole for a specified time p.12
8. Constructing an inference predicting emptying time of soapy water and other liquids p.12,13

.Beading of Water Columns

9. Identifying the beading effect of water columns p.116
10. Constructing an inference relating length of unbroken water column to hole size p.17
11. Demonstrating length of unbroken water column for five different size holes p.18
12. Applying a rule to predict relation between hole size and beading effect p.18
13. Ordering results in a graph p.18
14. Applying a rule to predict beading of soapy water p.19
15. Interpreting results of demonstrations in terms of causes -stating a rule p.19

.Heaping and Drops

16. Identifying heaping behavior of water p.23

17. Applying a rule to predict heaping behavior of soapy water p. 24

18. Demonstrating validity of rule by testing soapy water p.24,25

19. Applying a rule to predict heaping behavior of other liquids p.26

20. Demonstrating validity of rule p.26

21. Applying a rule to predict size of drops of plain and soapy water p.26

22. Demonstrating validity of rule p.26

23. Describing dops of various liquids on various surfaces p. 27

.Balances - A Way to Measure "Heaviness" and Grabbiness"

24. Demonstrating use of balance p.32

25. Demonstrating "heaviness" and grabbiness"

26. Ordering results into graphs p.36

27. Interpreting results in terms of "grabbiness" p.39

.Tugs of War and the Skinlike Effect

28. Applying a rule to predict behavior of a loop of thread when soap is added to water p.41

29. Describing effect of adding soap p.41

30. Interpreting results in terms of stated or revised rule p.41

31. Constructing aninference to predict what happens when alcohol is added to water p.42

32. Demonstrating validity of model p.42

33. Applying a rule to predict effect of adding soap to powder floating on water p.43

34. Demonstrating validity of model p.43

35. Applying a rule to predict effect of adding soap to oil floating on water p.44

36. Demonstrating validity of model p.44

37. Applying a rule to predict success of floating paper clips on water p.44

38. Interpreting relationship of sinking paper clip to model p.45

.Absorption and Evaluation

39. Describing evaporation of water from a paper towel p.50

40. Applying a rule to change rate of evaporation p.52

41. Demonstrating validity of rule p.52

42. Describing rate of absorption p.52

43. Describing variable affecting rate of absorption p.53

44. Applying a rule to predict rate of absorption of soapy water, alcohol and oil p.54

45. Interpreting relation of results to model p.55

46. Demonstrating validity of model in capillary tubes p.53

47. Demonstrating validity of model by use of two glass plates of varying distance apart p.56

48. Demonstrating validity of model with blotter paper strips of varying width p.58,59

Classification of Behavior in Kitchen Physics into the Seven Levels of the General Hierarchy

Hierarchy	Behaviors
VII Demonstrating Validity	3, 11, 18, 20, 22, 32, 34, 36, 41, 46, 47, 48
VI Interpreting Relationships	4, 15, 27, 30, 38, 45
V Apply Rule	5, 7, 10, 12, 14, 17, 19, 21, 28, 33, 35, 37, 40, 44
IV Ordering	2, 6, 8, 13, 26, 31
III Describe Similarities and Differences	29, 43
II Describe Properties	23, 24, 25, 39, 42
I Identify Name	1, 9, 16

IV A Process Measure for ESS

The AAAS Process Measure is based on the answers to two questions. First, is there a sequence of behaviors which can be identified as prerequisite to a final task? Second, can a sequence of skills be identified that are necessary for efficient progression through a hierarchy of behaviors? Affirmative answers based on the work of Gagné (1) led to the development of the AAAS Processes (2). For example, the Observing Process has a number of terminal tasks such as "Ordering the germination rates of various seeds and seedlings from fastest to slowest" (3). Behaviors prerequisite to this are analyzed into sixteen lower levels under the Observing Process and supplemented by behaviors from three of the remaining eleven processes. This one terminal task in the Observing Process, while specific to a particular content, is at a much more complex level than behaviors at the beginning of the Process. The terminal task represents a learning set which includes many of the classes of tasks in the subordinate learning sets. By the time the child has completed the Observing Process between kindergarten and grade three, he has demonstrated the competencies necessary or basic to the behavior of observing.

Just how generalizable are the processes? The skill obtained can be viewed as accumulated learning of content and as more abstract behavior- "Previous learning, acquired through a number of encounters with similar problems, can establish a kind of capacity." (4) According to Gagné, mediation (positive transfer) occurs between learning sets because of elements shared in common- specific content or abilities acquired in practice. That the learning of skills in one context can facilitate the acquisition of skills in a different context has been recently demonstrated in a science program (5).

The "ESS Process Measure" derived from the General Hierarchy is based on the assumption that behaviors learned in one context can be measured in a much different one. For example at level IIB of the General Hierarchy (page 9), the child studying Small Things engages in a class of behaviors- "Describing properties of an object or event." According to the ESS philosophy, what the teacher encourages the child to do is to describe what he sees as fully as possible rather than give an accurate description of a cell. In this case the stimulus really does not matter because what he is learning is a rule which could be stated as: "Adequate" descriptions use a variety of senses and are quantitative wherever possible. In the first case, the rule is to state a certain class of facts. In the second case, the rule concerns how to go about describing. The facts can be complex as in concept learning but the "how to" is of a different order of learning more similar to Gagné's level 8- problem solving (6). At higher levels of the General Hierarchy the same analysis applies except facts are increasingly at more complex levels of principle learning. Thus for an ESS General Hierarchy, the answer to the first question asked in the AAAS Process Measure is about criteria of performance. If the child is able to describe an object or event adequately, it is more likely that he will be able to describe similarities and differences in a satisfactory manner. The answer to the second question concerning efficient progression involves the complex problem of inquiry or discovery teaching. It is suggested here that the General Hierarchy may provide a useful structure in the analysis of this topic.

The Process Measure developed for the ESS material may be discussed in terms of the S-R model. When the child is presented with a geometric shape and requested to describe it, there are many stimuli present. The shape has little to do with the context of the original learning situation where the child used a microscope examining cells. However, it is not entirely different. A person brings habits of describing with him which may or may not be changed in the learning situation. Also the description of geometric shapes shares a few elements in common with describing some geometric structures observed in cells or tissues. The significant stimulus is the question for it elicits the behavior of describing according to the rule previously mentioned. The stimulus is only the occasion for the response to be exhibited. Certainly if the stimulus has nothing to do with the response, the appropriate responses will probably not be elicited. In summary, the stimuli in the ESS Process Measure have elements in common with stimuli in the ESS units-Small Things and Kitchen Physics. The elements are not facts related to the discipline of biology or physics but are of a more operational level found in learning behavior classified under problem solving.

A curious aspect of this is the role of content. If content objectives are "assumed" to the detriment of learning rules for describing, the amount of transfer would be lower. The questions we would like to answer is what is the role of the content in learning inquiry and at what point does emphasis of the content become detrimental to learning how to describe, compare, apply a rule, construct and demonstrate?

Following are the process test materials given to teachers.

Process Measure - Comments for Teachers

The enclosed process measure is a continuation of the evaluation we discussed this summer. It is more objective and abstract than before to provide a sensitive indicator of science learned as a process rather than a body of facts. What we gain from this process measure may assist all of us in classroom evaluation. Participation in this is strictly voluntary and is just one of the follow-up activities being offered. Because of the large number of teachers and administrators interested in this evaluation, you are requested to return all of the enclosed forms within one week. Please give the measure to five or six students by selecting every fifth student as they occur in your roll book. When you finish teaching the ESS unit(s), return the enclosed post card with your name and address and request the process measure to be returned so you may give it to a second group of different students (every fourth on the roll). These general results will be related to a final brief written evaluation that everyone may take in the spring. In the final report, all of the results will be coded to protect the anonymity of all those participating.

In order to standardize as many factors as possible, the process measure should be given orally to one student at a time between 9:30 - 11 a.m. on any day except Friday. The teacher should be seated opposite the child at a table cleared of any other objects. The table should be away from the main activity of the class so the student is not distracted.

All of the instructions to the child are spoken by you as they are written in capital letters on the direction sheet. You begin the measure by saying I AM GOING TO ASK YOU SOME QUESTIONS BUT I AM NOT GOING TO SAY IF YOUR ANSWER IS RIGHT OR WRONG. DO AS WELL AS YOU CAN AND TELL ME WHEN YOU ARE FINISHED ANSWERING. WHEN YOU TELL ME YOU ARE FINISHED, I WILL ASK YOU THE NEXT QUESTION. YOU WILL NOT BE GRADED ON THIS. You then ask question #1 and when the child indicates the answer is finished, you respond with O.K. or All Right and proceed to the next question. It is important to avoid indicating through any expression whether the answer is classified as "complete" or "incomplete". If the child asks what you mean by a question, just say ANSWER WHAT YOU THINK I MEAN. Repeat the question if asked but do not interpret what you think it means to the child. In other words, it is important to limit your conversation to the statements written in capital letters.

There are eighteen boxes on the answer sheet. Place a _1_ in the box if the corresponding question is "complete". An answer is "complete" if _all_ the items listed after alphabet letters are given. Some questions have only one answer, some have two and three that must be given to be scored as _1_ or "complete". If the child has given all but one of the items required for a "complete" answer, do not pause or ask for more information but continue giving the process measure at your normal rate. If the child asks if you want more, just say JUST TELL ME WHEN YOUR ANSWER IS FINISHED AND I WILL ASK YOU THE NEXT QUESTION. When the answer is "incomplete" (one or more items missing), place an _0_ in the corresponding box. The answer given by the child does not have to be exactly like the one listed under a,b,c but must be a reasonable equivalent. Keep the answer sheet out of the child's sight so he will not see if there is a change in scoring. Some of the children will miss some of the answers. It is important for you to practice giving the measure prior to its use.

Process Measure Evaluation Instructions

Instructions to the Teacher	SPOKEN INSTRUCTIONS
Place on table red plain triangle red triangle with x up blue square To the side place envelope (with #2 up) and paperclip	1. POINT TO THE OBJECT WITH THE BLACK MARK a. points to the x WHICH OBJECT IS THE BIGGEST? b. points to the square (mark box #1 with a 1 if both a and b are answered.)
	2. POINT TO AN OBJECT WITH THREE SIDES a. points to the triangle POINT TO THE LONGEST SIDE OF ANY OBJECT b. points to long side of triangle
Hand the red triangle with the x to the child.	3. CAN YOU DESCRIBE THIS TO ME. YOU MAY HOLD IT a. mentions at least four characteristics such as texture, color, markings, shape, flexibility, smell, etc.
Hand paperclip to child. Place to side when finished	4. DESCRIBE THIS TO ME a. mentions at least four characteristics as above
Place plain piece of $8\frac{1}{2}$" by 11" paper on table and remove when answer is finished	5. HOW MANY PAPERCLIPS WIDE IS THIS PAPER? a. uses paperclip to measure and then says how long or wide it is in terms of "paperclips" (length or width)
Hand red triangle (plain) to child	6. WHAT COULD YOU DO OR USE TO DESCRIBE THIS MORE ACCURATELY OR IN MORE DETAIL? a. mentions the use of some quantative measure such as a balance or ruler or some arbitrary unit (as paperclips")

Remove blue square from table and empty envelope 2 containing green triangle with x green pentagon with x blue plain triangle You now have five figures on the table for questions 7,8, 9. When question #12 is finished, replace the three objects in envelope 2.	7. CAN YOU TELL ME HOW THESE ARE DIFFERENT a. describes four differences such as size, shape, color, marks
	8. HOW ARE THEY ALIKE? a. mentions at least two similarities: all straight sides, points, flat, with color, same material, etc.
	9. WOULD YOU SEPARATE THESE INTO TWO GROUPS a. divides objects into two groups
Hand green square to child	10. INTO WHAT GROUP WOULD YOU PUT THIS? a. places it into one group
	11. WHY DID YOU PLACE IT THERE? a. identifies basis of classification which must be consistant with what was done
If the child has classified the objects according to: shape - then give him the irregular blue shape color - then give him the black triangle markings - no markings then give him the blue triangle with spots	12. WHAT GROUP WOULD YOU PUT THIS IN? WHY DID YOU PUT IT IN THAT GROUP? a. identifies change in classification enabling logical inclusion of new object. Allow child to reorganize groups if he wishes
Remove all objects from table and replace with (all plain) blue triangle blue square blue six-sided figure Keep five-sided blue object out of sight	13. I HAVE ANOTHER FIGURE THAT IS PART OF THIS GROUP. I WILL PUT IT ON THE TABLE IF YOU CAN TELL ME WHAT IT LOOKS LIKE. a. put it on the table only if the child describes it as blue and five sided (if he does not describe both characteristics, place a 0 in #13)

Push the group of blue objects to one side and place in front of child the green triangle, green square and green five-sided figure. Do not arrange.

14. THIS GROUP IS LIKE THE FIRST. CAN YOU TELL ME WHAT FIGURE IS MISSING?
    a. describes it as green and six ore more sided. place it on table even if he gets a 0

Push group of green objects to other side except the five-sided one. To the green five-sided one add a blue triangle and a black six-sided figure.

WHAT FIGURE IS MISSING FROM THIS GROUP?
    b. describes it as red and four-sided (or square). place on table only if he gets a 1

Remove all objects from table and place paper with seven figures in front of child so he may easily read the words "group one" "group two"

15. THERE ARE TWO GROUPS OF FIGURES ON THE PAPER. EACH GROUP HAS FOUR FIGURES. IS ANY ONE FIGURE IN BOTH GROUPS?
    a. identifies three-sided figure

HOW MANY FIGURES ARE THERE? ALL TOGETHER?
    b. seven

HOW ARE THE TWO GROUPS DIFFERENT? HOW ARE THEY THE SAME?
    c. mentions at least one similarity such as both groups have same shapes and one difference such as one group gets bigger than the other

16. CAN YOU TELL ME ABOUT JUST ONE CHARACTERISTIC OF THE FIGURES THAT STAYS THE SAME IN ONE GROUP AND CHANGES IN THE OTHER?
    a. identifies length of sides or center lines stay the same in one group and change in the other

17. HOW COULD YOU SHOW THAT YOU ARE CORRECT?
    a. indicates some way such as measuring

18. TELL ME WHAT THE NEXT FIGURE IN EITHER GROUP WOULD LOOK LIKE.

a. describes it as seven sided and for group
   - I - either small or triangle sharper or center line same length
   - II - either larger or sides same length or center line longer (child must describe figure in at least two ways for answer to be rated as complete or 1. Number of sides must be mentioned with one more statement about it).

Evaluation Score Sheet Teacher code number (b)____________________ (see below)

Name of student	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	a	b

in "a" blocks place an x if the child is in the top third of class
y if the child is in the middle third
z if the child is in the lower third
(does not have to be exact base, xyz on your estimation of academic performance)

b spaces leave blank for assigning a code number

Dates of giving process measure____________________

	Date began	Date completed	Approximate number of hours spent on unit	Average length of lesson on any day
Small Things				
Kitchen Physics				

Make any comments on the back of this paper (1) how "successful" was the unit? (2) have you ever administered a measure like this before? (3) did you have any particular difficulty with giving it? (4) what behaviors of the child did you notice while administering the process measure?

Materials for Process Measure

Process Measure-Comments for teachers, three pages

Process Measure Evaluation Instructions, four pages

Evaluation Score Sheet, one page

One manila envelope 3½" X 2¼" with flap opening at narrow end. On plain side in the center is printed the number 2 about 1" high. Along the long edge of the same side are lines approximately 3/16" apart which serve as a measuring device.

One smooth 1¼" paper clip, silver colored.

Seventeen figures made of heavy poster paper in four colors: light blue, medium red, medium green and black.

Five large (2" x 2" x 2and 3/4") triangles

- one blue
- one blue with four small black dots placed randomly in center of one side and three dots on the other side.
- one red
- one red with X placed on one side and roughed up surface on the other side
- one black

Two small (1¼" x 1¼" x 1and 7/8") triangles

- one green
- one green with X placed on one side

One large (2" x 2") blue square

Two small (1" x 1") squares

- one red
- one green

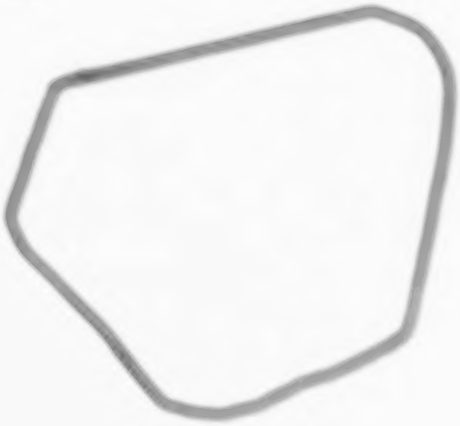
Three pentagons

one green (1 and 1/8" on each side)
one green (1 and 1/8" on each side) with X placed on one side
one blue (1" on each side)

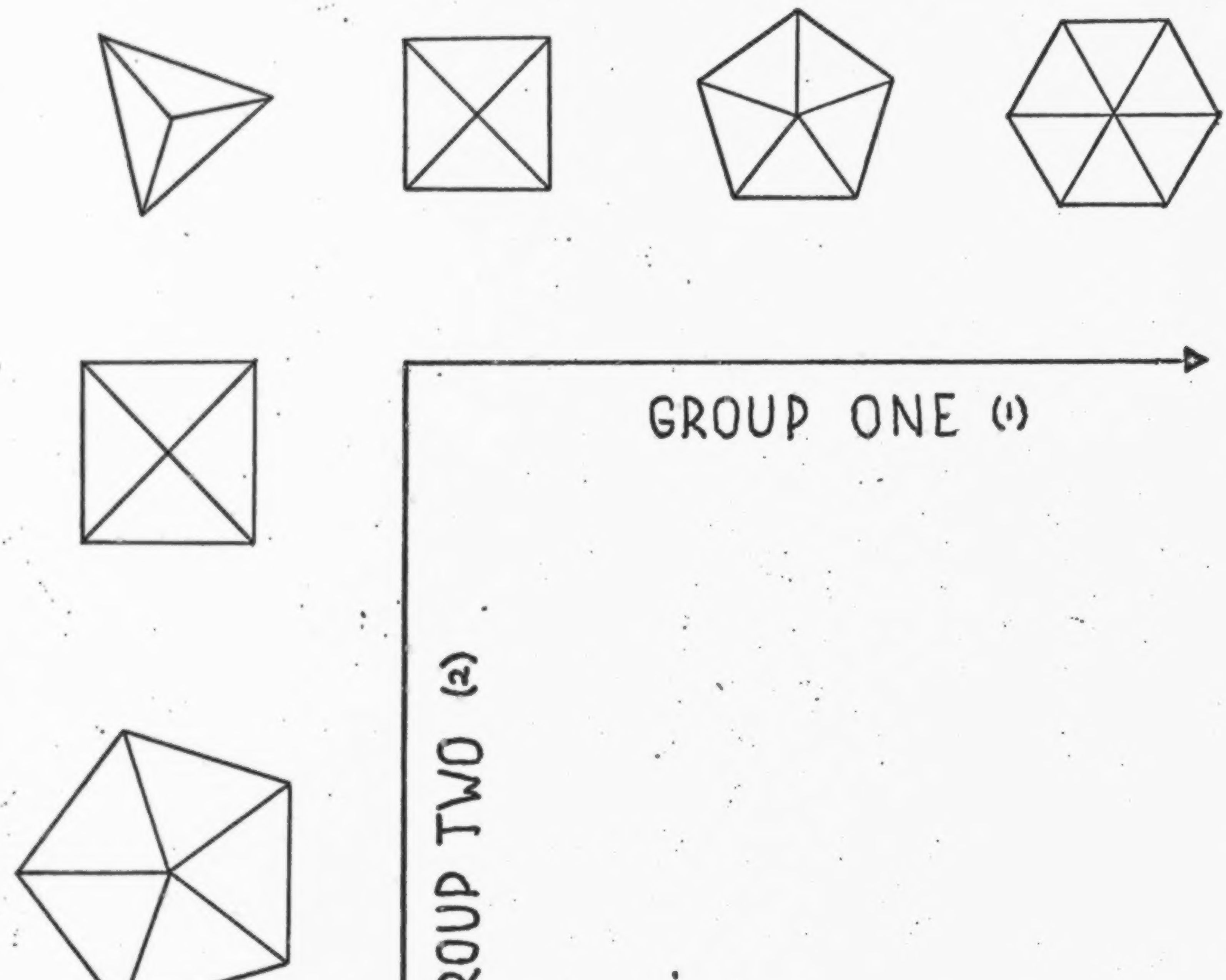
Three hexagons

one blue (1" on each side)
one green (3/4" on each side)
one black (3/4" on each side)

One irregular-shaped figure in blue



One 8½" x 11" sheet of paper on which there is printed seven figures divided into two groups.


GROUP ONE (1)
GROUP TWO (2)

Definition of Acceptable Learning Set for Analysis of Transfer Between Learning Sets

An acceptable learning set is represented by a plus (+) sign and is defined by the following combinations of acceptable (1) and unacceptable (0) responses to the paired questions in each learning set.

01
10
11

Transfer between single learning sets has the following possible combinations consistant with positive transfer (lower to higher)

+	+	-	-	+	-
01	01	00	00	01	00
01	10			10	
01	11			00	
10	01				
10	10				
10	11				
11	01				
11	10				
11	11				

Transfer to a higher learning set when a subordinate learning set is unacceptable (-) is contradictory to the hierarchy as in the following combinations (lower to higher)

-	+
00	01
00	10
00	11

Transfer from two learning sets together occurs once in the "BSS Behavior Hierarchy"

IV A	IV B		V
9,10	11,12	⟶	13,14

An acceptable double learning set (+) is defined by the following combinations:

01	01
01	10
01	11
10	01
10	10
10	11
11	01
11	10
11	11

An unacceptable learning set (-) is defined by the following combinations:

01	00
10	00
11	00
00	01
00	10
00	11
00	00

Transfer from the double learning set to the single learning set would then be analyzed by all possible combinations found within the four types of transfer (1) + to + (2) - to - (3) + to - and (4) - to +

The above analysis is based on reference (6)

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V. PROCESS MEASURE RESULTS

During the 1966-67 year, twenty-one teachers from the Washington metropolitan area voluntarily participated in the evaluation. As is seen in the summary of "Teachers Participating in Evaluation" they represented a wide variety of situations. They taught in rural and suburban areas of four counties. They included three grade levels 4, 5, and 6. Five teachers gave only a "before" test to their students which was intended as a control before being exposed to the ESS units. Ten teachers gave only an "after" test after studying one or two ESS units. Only four gave both "before" and "after" tests that were included in the final calculation. Three results we omitted because of late return or other errors. The "after" tests given shortly after completing the units were spread over a five month period between November 1966 and April 1967. The Baltimore subgroup, teacher number 21, was a special case. Of the fourteen teachers giving the after test, five taught both Small Things and Kitchen Physics, one taught Kitchen Physics only and the remaining eight taught only Small Things. Of the twenty-one teachers participating in some part of the Process Measure, fifteen also gave a content test to be discussed in the next section.

Needless to say, many selection factors could be operating to influence the results. There is enough data however to help one decide whether an experiment under carefully controlled conditions is of value.

Teachers Participating in Evaluation

Teacher	County	Grade	Number of Test Subjects		Month BSS Units Completed		Content Test
			Before	After	ST	KP	
1 Mrs. T	A	6		14	11/66	2/67	Yes
2 Mrs. P	A	4	5		12/66	2/67	No
3 Mrs. G	A	5	5	(7)	2/67	4/67	Yes
4 Miss W	A	4	5				No
5 Mrs. G	A	4	6	7	10/66	3/67	Yes
6 Miss M	M	5		6	3/67		Yes
7 Mrs. R	M	6	6		1/67		Yes
8 Mrs. A	M	5		6	11/66		Yes
9 Mrs. B	M	6	5		2/67	6/67	Yes
10 Miss B	M	6	6	12	12/66	4/67	Yes
11 Mrs. H	M	5		6	12/66		Yes
12 Mrs. F	M	5	5	(5)	3/67		Yes
13 Mr. H	M	6		13		11/66	No
14 Mrs. J	M	5		5 (6)	12/66		No
15 Mrs. C	P	4	6	5	12/66		Yes
16 Mrs. T	P	5	7				No
17 Mrs. B	P	6		6	1/67		Yes
18 Mrs. L	P	6		7	1/67		Yes
19 Mr. Y	P	4		7	6/67	5/67	Yes
20 Mr. H	P	6		7	3/67	3/67	Yes
21 Mr. S	B	4&5	34	36	11/67		No

County: A-Arlington, M-Montgomery, P-Prince George's, B-Baltimore
BSS Units: ST-Small Things, KP-Kitchen Physics
Numbers in ( ) not included in IBM data

Do the students improve in behavioral skills as a result of studying the ESS units? Eighteen items in the process measure assess the nine learning sets. By the criteria that one correct response out of two define an acceptable learning set, then all learning sets reflect an improvement

Learning Set	Process Questions	Average Improvement*
I	1, 2	+0.1
II A	5, 6	+10.3
II B	3, 4	+9.0
III	7, 8	+20.7
IV A	9, 10	+1.0
IV B	11, 12	+9.5
V	13, 14	+4.3
VI	15, 16	+11.0
VII	17, 18	+17.0

The average correct response before studying ESS was 60% (Chart I) and after studying ESS it increased to 68% (Chart II).

Such an over-all description is not very meaningful for reasons of validity, reliability and purpose of the measure. We do not know for example how equivalent the "before" and "after" groups are on any other factor. The fact that some teachers who gave the "after" test were knowledgeable about it compared to others who did not also give a "before" test quite likely had some influence.

Of greater interest is the improvement or possible transfer on individual items. The profile of a subgroup from Baltimore (graph II) closely agrees in the area of improvement with the other groups (graph I). Over-all the Baltimore group had twice the improvement. This might be explained by the fact that the Baltimore teacher (#21) was highly experienced with ESS materials and had conducted many programs for teachers in using ESS units - especially Small Things. This assumption would have to be tested under controlled conditions before it could state with much reliability. A strong support comes from examining the items of improvement. Gains of over 20% occur in eight items of the Baltimore group. Gains of over 10% occur also in eight items of the earlier group and five of the eight are the same items. On six items of least improvement the groups also closely agree. (Chart IX)

---

*calculated from Chart IX

Another subgroup (excluding Baltimore) was examined to see if there was any differential performance on the "after" test between children who studied Small Things only compared with those who also studied Kitchen Physics. This second unit was not examined separately since only 13 children studied it alone. The earlier analyses of Small Things behaviors into the seven levels of the General Hierarchy (page 8) demonstrated most of the activities in the first three levels. For Kitchen Physics, most of the activities are in the upper three levels V, VI, VII (p. 28). The group doing both units had a greater number of acceptable responses. This effect does not appear to be a function of grade level (graph VI and VII) but may very well be a result of the fact that brighter groups do more work. We can still examine where the greater performance appeared. With the addition of Kitchen Physics with its strength at the upper levels we would expect a large part of the improvement to be at levels V, VI, and VII compared to I, II, III. This appears to be the case (Chart IX).

Levels	Percent Differences Totaled
I, II, III	- 3.9
IV	+ 32.3
V, VI, VII	+ 48.2

Teachers also classified their students into three groups of academic ability, although only one-fifth of their students were placed in the lower third. The verbal I.Q. was obtained for thirty-six children with the following results:

Group	Number of Children	Average I.Q.	Range of I.Q.
X	14	122.4	98 - 137
Y	11	109.8	93 - 129
Z	11	96.2	73 - 125

Graph profiles show that the lower third did not improve in performance after studying the ESS units (graph V). Final performance of the middle and upper third were very similar although "before" performance of the upper third was superior (graph III). The greatest increase in performance therefore was with the middle third (graph IV).

Validation of the Hierarchy

Examination of eighteen individual items in the Process Measure allows comparison of difficulty level between question pairs in each learning set. For example, in the Before test (chart I) questions one and two under learning set I are evidently equally difficult while this is not true of questions three and four under learning set II B. Note that learning set II A has not been included in the final calculations since it is quite different from the others in a manner to be described later. Although 3.6% of the responses for questions one and two were "unacceptable" (see page 42) all[*] of the responses for learning set I were "satisfactory" since there were no occurrences of both questions being missed by the same individual. In other words, an acceptable learning set is defined as one or both questions being "acceptable."

Positive transfer between learning sets is identified as occurring when behavioral competencies in the lower learning set "mediate" or increase the probability that the learner will be competent in performing behaviors at the next higher learning set. When the higher learning task is not attained, then learning experience background is inadequate - the learner lacks prerequisite behavioral competences. Given ten individuals one will have ten different patterns of behavioral competencies possessed. This is one description of "individual differences."

It is quite possible that a higher learning set will be satisfactory when the lower learning set is not. This can be explained in two ways. Either the task used to assess the lower learning set is too difficult or it is not necessary for performance of the higher level task. Both cases are a problem of proper definition of tasks necessary for "mediation"[**] between learning sets. It is also a problem of language. A higher learning set will not possess all of the behaviors found in the lower learning set. The behaviors not possessed in the lower learning set may not all be necessary for the higher task. One result of an instructional program is to reduce individual differences. As a result of a success program, we should see a higher proportion of terminal tasks attained as well as an increase in "acceptable" learning sets subordinate to the terminal task. The proportion of instances consistent with positive transfer should therefore increase.

[*] All but one.
[**] This problem is discussed further in the summary.

The percentage of learning sets (L.S.) acceptable increased from 69% in the before group (chart XV) to 80% in the after group (chart XVI). This 11% increase was larger than the 6% average increase observed in the eighteen individual items of the Process Measure - from 60% to 68% (chart I, II). The higher percentage values of learning sets is due to the definition of acceptable L.S. as one or both questions in the Process Measure being satisfactory (01 or 10). All of the learning sets reflect an improvement comparable to the averaged of paired individual questions (page 47) with the exception of L.S. VI and questions 15, 16. This is a result of a large reduction in ambigious answers (01 or 10 or 11 or 00) for the learning set (chart XIV).

The two most obvious differences between before and after groups are the twofold increases in individuals achieving terminal learning sets and achieving all learnings sets.

The following results are summarized from charts XV and XVI.

	Percentage of Satisfactory Responses Before Group	After Group
Achieved terminal Learning Set	27%	56%
Achieved all Learning Sets	14%	30%
Missed only terminal L. S.	9%	9%
Missed a subordinate L. S. and all higher ones	12%	11%
Missed a subordinate L. S. and achieved a higher L. S.	63%	52%

The proportion of transfers within the hierarchy increased from an average of .85 in the before group (chart X) to .88 in the after group (chart XI). The improvement appears to be in the first four levels of the seven levels of the General Hierarchy (page 9) but a differential effect of the two ESS units has been suggested on page 48 (chart IX column 3).

An increase in acceptable responses does not necessarily result in an increase of instances consistent with positive transfer. For example, the number of students that could not respond satisfactorily to questions 3 and 4 (L.S. IIB) decreased considerably but the proportion of instances consistent with positive transfer changed very little. The increase in satisfactory IIB learning sets is reflected in the increased proportion of instances consistent with mediated transfer (chart XIII) compared to the before group (chart XII). There was also a slight increase in instances inconsistent with mediated transfer (* - *) as would be expected from the stability of instances consistent with positive transfer. Thus the difference in proportion of .60 in the after group is due largely to an increase in acceptable learning sets (*).

A measure of reliability is offered in the idea of ambiguity. In this situation a learning set is scored acceptable with only one question correct. This follows the criteria used by AAAS in scoring their competency measure but differed from Gagne who used a definition of both answers required to be correct. His definition of ambiguity was thus based on missed learning sets. In this paper little change was found in ambiguity between before and after groups. The respective values of .32 and .30 (chart XIV) are ten times higher than the value of .03 reported by Gagne.

The General Hierarchy model assumes an increasing order of difficulty. Consequently, with an increasing number of intervening learning sets, the frequency of pass to fail relationships should increase. This pattern is observed in chart XVII with the exception of four learning sets. This result is due to the high percentage (71.3) of acceptable responses for question 13 (chart II) which caused a large number of Learning Sets VI to be satisfactory.

VI. Content Test Results

At the end of the 1966-67 academic year, the content test was made available to six different groups of teachers (chart XX). Each of the seven content questions was tentatively identified with one of the seven levels of the general hierarchy. There was no relation between scores on the content test (chart XXI) and the process "after" measure (chart XVIII) for those subjects taking both tests.

The only content test item that children who studied the Small Things unit were more successful with was number one. According to the "criteria for acceptable response" (p.33) they were able to draw a "recognizable" cell and label two or more structures. With the exception of this item, all fifth grades had similar profiles for the remainder of the test. On the basis of partial verbal I.Q.'s available (chart XIX) the groups were equivalent. The biggest factor in both content and process test performance seems to be in the "academic" category identified by the teacher. Those classified as in the upper third performed much better than the middle and lower third (chart XXIII). This analysis does not show much relation between performance on the separate items.

Although the fourth graders appeared to have the highest I.Q. as a group (although too few were available to say conclusively) they did not do well on the content test. This did not appear to be true of their performance on the Process Measure which was all oral and manipulative. Thus, on written tests, the fifth grade appears to be the minimum level to obtain an evaluation more consistent with an oral test.

Scoring Key for "Questions on Small Things" Content Test

Question	Criteria for Acceptable Response
1	Construct a "recognizable" cell and label two or more structures - nucleus, interior, cell wall or outer part, storage, etc.
2	Order of B A C D only
3	Identify second choice only
4	Identify one of the following ideas - - Idea of function - some cells or parts do different things Idea of environment - cells are affected by more water (roots), sun (leaves)
5	Identify one of the following ideas -- Idea of movement - if they move, they are alive Idea of response - if they eat, or move when stimulated If they look like a plant, animal or cell
6	Describing four or more characteristics
7	Identify an appropriate shape with function

2

Questions on Small Things Name ____________________

1. Draw a cell and name its parts.

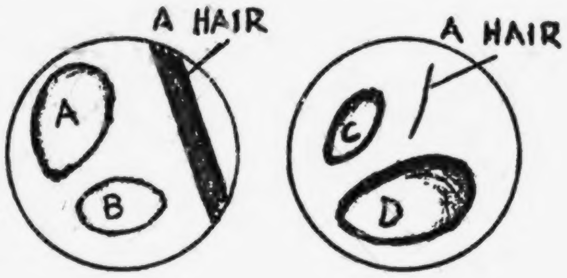
2. These four objects - a,b,c,d - are seen through a microscope and a magnifying glass. Arrange them in order of their real size by writing the letter of the object below.

_____ is the smallest

_____ is a little bigger

_____ is next to the biggest

_____ is the biggest really

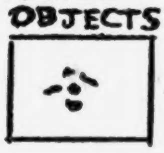


3. A boy has a small magnifying glass. He finds a seed that is just as wide as the magnifying glass. When he looks at the seed through the glass, the seed looks bigger and (check one)

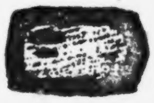
☐ he sees all of the seed at one time
☐ he cannot see all of the seed at one time

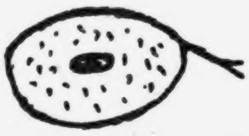
4. Why do you suppose the cells are different in different parts of the plant?

5. Here is a picture of some small objects. If someone gives them to you and asks you if they are alive, describe what you will do to the objects to find out if they are alive.

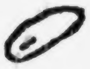


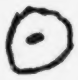
6. How many differences can you see between the objects below. List all the differences you see.

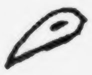


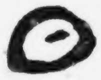


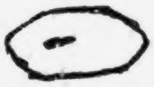
7. Place a circle around the cell that would be best for protecting the plant.

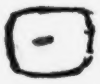












Why did you pick that one?

TYPICAL ANSWERS TO "QUESTIONS ON SMALL THINGS"

1. Answers marked correct generally were similar to this one.

Most children labeled the cell wall and nucleus; many also labeled protoplasm. A few labeled extensively, even including mitochondria and endoplasmic reticulum.

Most incorrect answers were blank, or had the cell but had no, or not enough, labels. In Group I many children copied the illustration for question 2. Groups I and II generally had no basic understanding of the structure of the cell. Group V had correct answers, but they were not detailed. These cells were labeled "inside", "outside", etc. Group VI answers were generally correct but not detailed, although some showed knowledge of the division process of cells. In Group IV two classes showed a very good understanding of cell structure, while five other classes showed a very poor understanding. Group III labeled more parts to the cell more specifically. Labels in this group included protoplasm or cytoplasm, nucleolus and chloroplast.

4. Most children answered this question by saying that each cell has a different job to do. Some said because the plant looked different in different parts, and some noted difference in environment. Some typical answers were:

> "One would bring in water and food. One would bring in sunlight. One would bring in air."
>
> "Different parts of the plant need different cells to do different things like..."
>
> "Because not all the plant looks alide and the cell takes the shape of the part of the plant it's in."
>
> "Some parts get more sunlight. Some parts have different texture. ...grow under the ground,...carry water,... carry minerals,...have different color."

Generally, wrong answers compared different plants instead of parts within the plant, compared plants to animals, or said the cells were different because the plant has different cells. A few noted that cells are different in different parts of humans and so they must be different in plants, too.

5. The most typical correct answer for this question was: "You can put them under a microscope and see if they move." Others were:

   "Give it some food and see if it eats."
   "Find out if there are any cells in the body. Can it produce?"
   "First what I might do would be to look at them through a microscope to see if they look like cells or small animals. I would also look for movement."

A widespread misunderstanding of either the question or the basic concept of characteristics of living things was evident. A number of the wrong answers can be represented by "Look in a microscope and see if they are alive," They exhibited extensive knowledge of the procedure for using a magnifying glass, a microscope, and a miniscope. Some gave explicit, detailed answers on preparation of a slide. But they all failed to cite those characteristics which would indicate that the objects were living matter.

6. In comparing the two objects illustrated, some children could contrast opposing characteristics, whereas some only listed the characteristics of each object separately. The differences most often noted were:

oval	rectangle
dots	lines
single nucleus	double nucleus
position of nucleus	
thin wall	thick wall
large	small
clear	shaded
smooth outline	fuzzy outline
has a tail	
animal cell	plant cell
living cell	crystal
nucleus clear	nucleus solid
(dot inside)	(dot outside)
eye	TV screen

A typical answer would list four or five of the above differences.

A few children noted only one difference:

"One has dots, one has lines."

"round---square"

A number of children listed as many as seven differences.

The younger children and those who have not studied the unit described the objects in more general terms than those who have studied it. The Seminar classes (particularly Group III) gave more descriptive and detailed answers. They referred to "cell walls" and "nucleus" where other children used "outside" and "blotches".

7. Most children chose the heavy walled cell to protect the plant best. They said it looked the strongest. Some chose the biggest. A few chose the pointed one because it looked sharp. Typical wrong answers were:

    "Because it looked like a leaf."
    "Because it looked like a seed."

Group III showed a definite superiority in basic comprehension of the principles tested. Groups I, II, and V showed generally poor understanding of the structure of a cell. In Group IV, two classes exhibited good understanding, while two classes exhibited very poor understanding.

One class which did not sign their names gave extremely poor answers.

Third version of content test

The content test that was finally given on Small Things at the end of the 1966-67 academic year was the fifth version to be developed. Two earlier versions are included here to show some of the development and responses given by children. As every test maker inevitably finds out, the responses to a question often sample a much larger universe of possibilities than is originally thought.

Summary of responses from one class on the third version of the Small Things test:

1.

first choice	9
second choice	0
third choice	14

2.

first choice	0
second choice	18
third choice	2
fourth choice	3

3. D C -- A 8 (B and E were accepted in either order)
E D -- A 4
C D -- A 3
others 8

4.

first object		second object		third object	
nucleus	17	cell wall (skin, etc.)	14	food vacuole	4
cells	2	outside cell	1	protoplasm	4
				particles	3

Most named it cell because "it looked like one"

5.

Number of differences named	Number of Students	Frequency of terms used to describe differences	
0	9	round	8
1	2	thin wall	7
2	9	more protoplasm	2
3	3	size	1
		size of nucleus	1
		no vacuole	1

5. (duplicate number)
All answers but two were correct

6. Characteristics of cells drawn
storage cells - more dots in cell, thin
protection cell - square, small, dark, sharp end
Number giving some response as above 9

7. Typical answers
   "useful for different things"
   "thicker wall"
   "one is round, other like a wall"

8. No 13
   Yes 7
   "sometimes it has things inside"
   "made up of sides"
   "If it were sugar it would be part of the sugar cane plant."

9. softer to chew 4
   makes it tender
   cells get weaker

10. Number drawing a recognizable animal 13
    Drawing did not match name of animal 3

11. Gave some valid reason 14
    Invalid 2
    Examples: must be from creek or lake
    tap water is purified, it has chlorine

12. Most common response "in living things" (8)

13.

	True	False
a	19	4
b	22	1
c	15	8
d	3	20

14. Twenty picked Johnny because it was complicated (probably had cells) or it moved most. Three picked Jeanne, two gave reason that water might have moved the object.

15. Eighteen picked Anne because it didn't move or dissolve when water was added, did not increase in size.
    Five picked Peter because living things react, got bigger.

16. Twenty picked Johnny because of complicated parts and most movement.

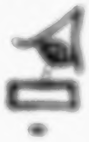
17. Is it moving? 9
    Does it have cells? 4
    Is it eating? 4

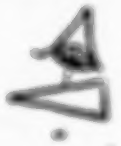
18. Unanimous yes

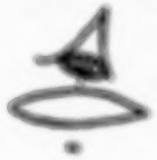
Third version of Small Things Test

QUESTIONS ON SMALL THINGS name______________________________

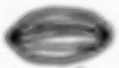
1. A boy is looking at a seed through a piece of glass. He looks through three different pieces. Circle the one that will make the seed look bigger.





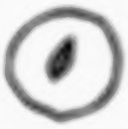


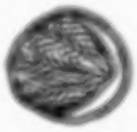
2. A seed is just a/wide as a magnifying glass when they are next to each other. When the glass is held over the seed, what do you think you will see? Circle the picture below that you think you will see.

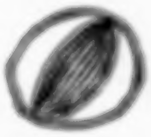


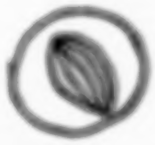
seed

glass









3. There are five pieces of an onion bulb drawn below. Although they are really different sizes, they are all drawn the same size. Arrange them in order of their real size, from smallest to biggest, by writing the number of the picture below.

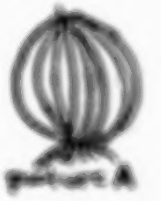
The smallest is _____

A little bigger is _____

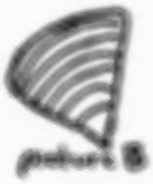
Even bigger is _____

Next to the biggest is _____

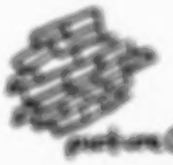
The biggest really is _____



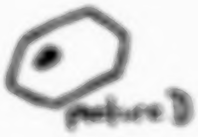
picture A



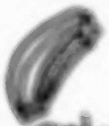
picture B



picture C

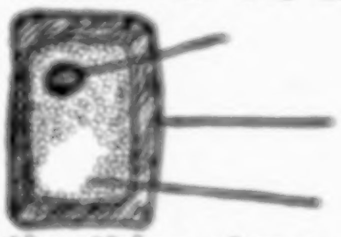


picture D



picture E

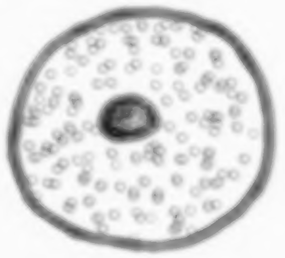
4. Give a name for the different parts of the thing below.



Give the thing above a name______________________________

Why did you name it that?______________________________

5. In what ways is this thing different from the one above? Write below as many differences you can see between the two things.



Give this thing a name______________________________

Why did you name it that?______________________________

5. The five kinds of plants below have cells in them. Draw a line between the parts of the plants that you think would have cells that look most alike.

celery leaf *　　* celery stem
tomato root *　　* onion root
fern stem　 *　　* carrot leaf

6.

Draw a cell that would be good for storing food in a plant.	Draw a cell that would.be good for protecting a plant.

7. Why do the cells you drew above look different? ____________________

____

____

8. Is a crystal a cell?__________ Why do you think so?______________

____

9. Why does cooking food make it easier to chew?_________________

____

10 Draw a picture of one of these animals- Amoba, Paramecium, Euglena. Circle the name of the one you drew. If you cannot draw one of these, draw another one you saw in the microscope and put its name here

____

11 When you are looking for living things in water, what difference does it make where you get the water?

____

____.

12. Where can you find cells? ________________________________

____

13. Write true or false after each of these statements. If you write false, then write a correct statement after it.

All living things move.__________

Small things to us may be large things to some other forms of life_____________

Living things have more water in them than non-living things.______________

Some parts of living things may not have any cells_____________

14. Johnny watched an object under his microscope. It moved around slowly. It looked very complicated with many little parts. Jeanne looked at another object under her microscope. It moved around. After a little while it stopped moving

Who probably had a living object?__________________

Why do you think so?_____________________________________

15. Peter watched an object under his microscope. It slowly got bigger. He added some water and it dissolved (went away). Anne watched another object under her microscope. It stayed the same size. She added some water but nothing happened.

Who do you think had a living object?______________________

Why do you think so?_____________________________

16. Of all the objects the four boys and girls watched, who probably had a living object for sure?__________________

Why do you think so?____

17. What kinds of questions could you ask to find out if one of the objects above was really alive? Number your questions.

____

____

____

____

18. Did you enjoy studying small things with a microscope?___________

What other things would you like to do with a microscope?__________

____

____

Fourth version of Small Things Test

The quotations listed below are taken from a tape recording of a 5th grade class discussion on the test. The quotes represent typical interpretations of questions.

1. first choice 6
   second choice 23

   "I have a coin collection back home and when I get the magnifying glass far away I can see it all and it still looks bigger."

   "I say you wouldn't be able to see all of it because if you look through a magnifying glass and the seed is just as big and looks bigger you wouldn't be able to see it all."

2. first object - nucleus 3 responses
   second object - outside, crust, skin 12 responses
   third object - inside, 4 responses
      Nine children identified it as a cell

3. Number of differences
   Eight children named one difference
   Eight children named two differences
   Seven children named three differences
   Four children named four differences
   One child named five differences

   Terms most frequently used to describe differences
      Round - 20
      Not as thick, edge, no wall - 12
      Bigger - 10
      No hole, space - 8
      Bigger ball inside - 5
      Ball is oval - 4
      More dots inside - 3

4. CDBA - 9
   DCBA - 8
   BACD - 5
   DBCA - 3
   BDCA - 2
   ABCD - 1

Bruce: "I think the smallest is picture D because it shows all the cells."

Mark: "Picture C because it shows only one cell."

Bruce: "Picture C is the next biggest because it has only one cell."

Mark: "I think the little bit bigger one is D because instead of just one cell it has many cells."

"Picture B is the second biggest because its a slice of the onion."

Bruce: "Well I change my mind about D and C because one cell is smaller than a bunch of cells."

Teacher: "How do you know?"

Bruce: "Cause it's different magnification...ah...It looks like the... one cell and there's a whole bunch of them so a whole bunch would be much more than...ah... how many ever more cells there are than one."

5. No - 28
   Yes - 1

"I say it's a cell because when I was looking under my microscope at salt and sugar you could see all the cell."

"I say it is not a cell because a cell is not a solid I don't think and a crystal does not have all the cell parts like a nucleus and wall."

"Well I think so because sugar lives in the beginning and then its taken off...it sort of dies."

"Well I don't think a crystal is a cell because you can't see a cell with your eyes. You need a microscope to see a cell and you can see a crystal of sugar without needing a microscope."

6.

Identifying	For protection	For food
first cell	2	3
second cell	5	16
third cell	2	7
fourth cell	20	3

For protection

"I say the second object because it's right in the middle of the food cell, or whatever you want to call it, it's right in the middle."

"I think it's the third one because I think it can move fast."

"I think it's the last one because it's got such a big thick wall."

For food

"The second one because it's fat and can probably carry a lot."

"The last one because it's circular and is able to change it's form and surround the food."

"I think it's the third one because it doesn't have as thick a cell wall and the nucleus is close to the cell wall."

"The second one because it's larger and would be more of an appetite for an animal."

"The second one because the nucleus is in the middle and its got more protection there...more vitamins or something."

7. Five selected Peter
Twenty-four selected Anne

"Anne because living objects don't disappear."

"I say Peter because his got bigger and when he added water it disappeared and there might have been some chemical in the water."

"Peter because it got bigger and when water was added it might have gotten frightened."

"We used to put salt on snails and they would dissolve."

8.

	Number of Responses
See if it moved	12
See if it looks like an animal	4
Can any living thing dissolve	2
See if it grows	1
What mixture Peter used	1
See if it eats	1
Reacts to stimuli	1
If it has cells or cell parts	4
Where it came from	2
Did it drink?	1

Ten children asked two questions.
Five children asked three questions.
Two children asked one question.
Two children asked four questions.

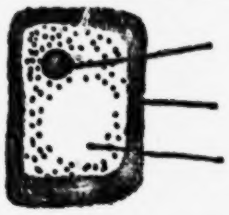
9. Eleven children identified some way to answer all the questions asked in #8.
Seven children identified one way less than the number of questions asked.
One child identified two ways less than the number of questions asked.
Seven children did not identify any way to answer their questions in #8.

Fourth version of Small Things Test

QUESTIONS ON SMALL THINGS Name________________________________

1. A boy has a small magnifying glass. He finds a seed that is just as wide as the magnifying glass. When he looks at the seed through the glass, the seed looks bigger and (check one)
   - ☐ he sees all of the seed at one time
   - ☐ he cannot see all of the seed at one time

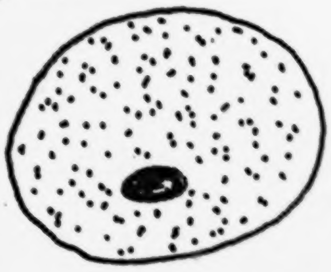
2. Give a name for the different parts of the thing below.



Give the thing a name.

____

3. In what ways is this thing different from the one above? Write as many differences as you can see.



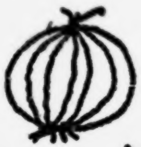
4. There are four pieces of an onion bulb drawn below. Although they are really different sizes, they are all drawn the same size as each other. Arrange them in order of their real size, by writing the number of the picture below.

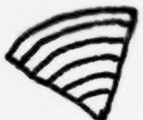
_____ is the smallest

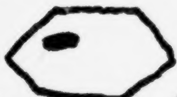
_____ is a little bigger

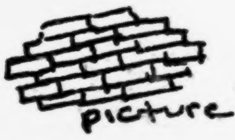
_____ is next to the biggest

_____ is the biggest really


picture A


picture B

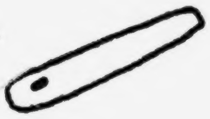

picture C

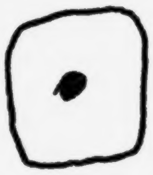

picture D

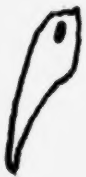
5. Is a crystal a cell?________ Why do you think so?__________

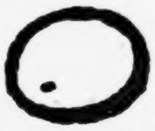
____

6. A number of different kinds of cells from one plant are drawn below. Which cell would be best for protecting the plant? Place a circle around the cell. Which cell would be best for making or getting food? Place an X over that cell.









7. Peter watched an object under his microscope. It slowly got bigger. He added some water and it dissolved (went away).
Anne watched another object under her microscope. It stayed the same size. She added some water but nothing happened.
Check which one had a living object

☐ Peter

☐ Anne

Why do you think so?________________________________

____

8. What kinds of questions could you ask to find out if one of the objects above was really alive. Number your questions.

____

____

____

____

____

9. Write just the numbers of your question above and after the number of each question tell how you would find an answer.

10. Did you enjoy studing the small things unit?__________
What did you enjoy about it?

VII Interaction of Students and Teacher

A classification of teacher and student behaviors one would expect to observe in a classroom were tentatively identified. Nine categories of teacher behaviors go from extraneous activity (00) to one of eliciting attitudes (09). Student behaviors that would be expected to result from teacher activities are arranged in the same nine categories (10 to 19). Statements from three ESS units to the teacher are then placed under the categories of behaviors one would expect to observe if teachers followed the suggestions.

One possible use of such an analysis is the prediction of levels one would expect to see more frequently in different units. Thus, the analysis below shows that a higher proportion of teacher "closed" "control" and "provoking" behavior" occurs in Small Things and a relatively greater proportion of higher level behaviors occurs in Mealworms. This reflects a fundamental difference in units where Mealworms allows a higher degree of experimentation than Small Things which is more of an observing unit.

Relative Proportion of Interaction levels

	Mealworms		Small Things
19	xx	19	
18	xxxx	18	
17	xxxxxxx	17	x
16	xxxxxxxx	16	x
15	xxxxxxxxxxx	15	x
14	xxxxxxxxxxxxxxxxxx	14	xx
13	xxxxxxxxxx	13	xxxxxxxxxxxxxxxxxxxxxx
12	xxx	12	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
11	xx	11	xxxxxxxxxxxxxxxxxxx

Teacher and Student Interaction Profile - Key

	Teacher Behavior		Student Behavior
00	Extraneous- not related to lesson, routine, disciplining	10	slouching, random attention
01	Closed- requesting specific response, informing	11	performing a specific task
02	Control- directing series of activities, gives vocabulary to be learned, giving approval or value judgment	12	asks non-operational, closed-ended questions
03	Provoking- stimulates questions or answers, provides open-ended answers	13	freely exchanging information, expressing opinion, attentive posture, questions determine activity
04	Develop- encourages (verbal or non-verbal) further inquiry, questioning, qualitative information, continuity from previous lessons	14	asks operational questions (data relating to cause-effect)
05	Investigate- enables experiment for quantitative data	15	use of instruments, identify and control variables
06	Recording- questions lead students to record results by which variation and trends may be readily observed	16	classifies data, records in a variety of ways
07	Evaluate- allows answers to remain partly ambiguous or unresolved	17	generalizes on experience and consensus (average), identifies variation in results, does not require adult approval or confirmation
08	Relate- leads student(s) to generalize experience, asking question that might be answered on basis of previous experience		
09	Attitude- elicits feelings about lesson, how child relates to it, meaning	19	takes work home, involves parents, expresses like or dislike (explicit or implicit)

Teacher and Student Interaction Profile- representative behaviors from three ESS units- Kitchen Physics (K), Small Things (S), Behavior of Mealworms (B)
Numbers ( ) refer to pages

	Teacher Behaviors		Student Behaviors
01	"This shouldlead them to discover that..." (S 9) "The onion Cells have thick, non-living cell walls..." (S 44)	11	"This circle represents the size of your microscope field." (S 19) "Suggestions for the proper care of mealworms at home should be ... (B 3)
02	"...the following demonstration will help direct their ..." (K 15) "A few questions could be asked which would point out..." (S 38) "You can suggest a procedure for tabulating..." (B 13)	12	"Assembling the Balance" (K 33) "Place your slide..." (S 16)
03	"...ask the class to predict how long it will take... (K 8) "If situations like this do not arise spontaneously, you may be able to create them." (B 6)	13	"...ask the child to observe..." (K 16) "What do you see..." (S 31) "Does he spend most of his time ..." (B 12)
04	"...some of the questions raised will have no clear-cut answers. But this should not prevent the children from wrestling..." (K 2) "Many times one can ask the child, 'How could we find out'?" (S 5) "This undirected activity provides a background for the more refined observations..."(B 3)	14	"Ask them to try placing your strips on one of their ordered graphs. This type of activity should contribute much to the children's appreciation of logically arranged data." (K 18) "Let your children try to work out..." (K 15)
05	"It is the method rather than the memorized facts we hope the children will retain and use." (K 1) "In this quantitative investigation the children learn..." (S 107)	15	"Let them test their predictions themselves by experimenting..." (K 10) "This exercise allows children to design and make equipment to test..." (B 16)

06 "Keeping a question list for future discussion and reference avoids side tracking and loss of continuity." (K 2)

07 "You will have to tolerate (and help the children to accept) uncertainty..." (K 2)

08 "If the children have not yet inquired about other substances ..." (K 12)

"...provides the children with another tool for revealing the differences and similarities between living and non-living ..." (S 91)

"You may want to call the children's attention to the notion that similar reactions to the same situations..." (B 9)

09 "...to give the child an awareness of the world of science and a way of approaching it and enjoying it." (K 1)

16 "Hopefully, they will think of keeping careful records..." (K 10)

Small Things Worksheets

"You can suggest a procedure for tabulating..." (B 13)

17 "...he begins to see the need to revise and correct his earlier misconceptions." (K 1)

18 "In trying to explain their ideas, the children should be urged to base their statements on their own experience..." (K 19)

19 "What does this investigation tell you about ..."(S 105)

VIII Summary

Transfer Between Process Measures

Science - A Process Approach is an exercise in pushing back the limits of generalizing experience by practice in a wide variety of situations. Its success must be largely attributed to attention given the conditions of learning as explained by Robert M. Gagné. The basic feature of these conditions are 1) the use of verbal directions to stimulate recall and 2) the use of verbal directions to guide instruction. The verbal direction can be described at three levels as they relate to the transfer of training.

First, behaviors as represented by action words basic to any inquiry are practiced within a wide variety of contexts - drawing from mathematics, physical and biological sciences. This variety assists the "lateral" transfer of behaviors from one context to another.

Second, the behaviors are arranged in a most obvious display of Processes such as CLASSIFYING to emphasize, I would judge, that the stress is not on some fixed content to be conveyed in an absolute sense but on a broad base of observable behaviors. This arrangement or hierarchy of behaviors beginning with the action words assist the teacher in determining what is being learned and to guide instruction accordingly. In this way, the learning sets represent a broad grouping of behaviors that have a practical use in the classroom and may be, most important, communicated to the teacher. Although this is important in lateral transfer, it fits more specifically the situation of vertical transfer where ideas are put together in increasing levels of complexity.

Third, specific activities of each unit provide a concrete model for strategies of teaching. *This is precisely the point of interest in applying the AAAS* discipline to an analysis of ESS. The question was "can suggestions for steps in thinking be placed in a structure analogous to the Processes?" This certainly might assist the task of communicating to the teacher. The analysis of the ESS units suggest a cycling back sequence in which the repetition of thought processes in an explicit logical ordering is basic to the putting of ideas together in going from simple concepts to complex principles

Transfer Within the Process Measure

In his 1962 study,* Gagné offers three kinds of evidence in discussing transfer among learning sets. Reliability of his measure is indicated by a very low ambiguious score (less than 3% for 01 or 10 answers on learning sets). The proportion found in this study was about 10 times higher (chart XIV) or 30-32% with very little change between before and after groups. Either the individual questions did not assess the same behavior or the criteria of acceptable responses were not closely equivalent.

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* Gagne,R.M., Mayor, J.R., Garstens, H. L. and Paradise, N.E. "Factors in Acquiring Knowledge of a Mathematical Task" Psychological Monographs No. 526 Vol. 76, No. 7, 1962. American Psychology Association.

A second measure is the amount of positive transfer from lower to higher learning sets with and without achievement of intervening learning set. The proportion successful on higher learning tasks when the intervening learning set was achieved averaged .70. When the intervening learning set was not achieved the proportion averaged .16 - a difference of .54. In this study there was a significant change in these values between before and after groups (chart XII, XIII).

Group	Intervening Learning Set Achieved	Intervening Learning Set Not Achieved	Difference
Before	.55	.14	.41
After	.69	.09	.60

These values reflect reduction of varying patterns of learning sets among the subjects. This is also, according to Gagné's definition, a reduction in individual differences. This results from the fact that a higher percentage of subjects had acceptable learning sets (+) and closely approached a limit of 100%. Although there was a greater relative change in the situation contrary to positive transfer (+ - +) compared to successful mediation of positive transfer (+ + +), this information does not show the tendency for learning sets to remain minus after encountering the first minus. The analysis of mediation learning sets would directly measure a change in patterns such as + - + - to + + - - if the total number of correct responses in both groups was identical. This situation, where the standard deviation would decrease with improvement of score, would be reflected where the scores were not closely approaching a limit.

A third measure showed the proportion of instances consistent with positive transfer. All of Gagné's values were above 0.97. In this study the values were not as high, averaging about .88 (chart X, XI). A considerably higher proportion of instances fell in the + + pattern in the after group.

Table 1

Change in Proportion of Pass-Fail Patterns *

	+ +	- -	+ -	- +
I to IIB	+.11	-.01	-.12	.00
II B to III	+.22	-.14	-.11	+.03
III to IV A	+.20	-.09	+.05	-.13
III to IV B	+.21	-.14	+.03	-.10
IV A,B to V	+.13	-.10	-.02	.00
V to VI	+.07	-.08	+.03	+.03
VI to VII	+.21	-.06	-.15	+.01
Total	+1.15	-.62	-.29	-.16

* Before group minus after group (Chart X-XI)

This is a second type of reduction in pattern of acquired learning sets which results simply from more sets being satisfactory (+). The relatively little change in values reflects the stability of the General Hierarchy.

Over-all the evidence suggests a reduction in individual differences between students as a result of studying the ESS units.

Frequency of Action Words

One of the assumptions of this study is that the nine action words can be ordered into a hierarchy of simple to complex. One may ask are the action words used in this way in the AAAS program? The analysis below shows no clear pattern except for "identifying and naming" occurring more frequently at the lower levels of the simple processes. These two action words occur twice as frequently as any others - making up 29.4% of the component skill behavioral statements. This supports the contention that "identifying and naming" are fundamental to performance of subsequent component skills or learning sets. The twenty three levels were grouped to give a total of 20-30 statements under each column.

Table 2

Frequency of Action Words Occurring at the Twenty Three Levels* of the Eight Simple Processes

	Levels									
	(1) 1-3	(2) 4-7	(3) 8-9	(4) 10-11	(5) 12-14	(6) 15	(7) 16-17	(8) 18-23	Total	Percentage
Demonstrating	3	1	6	6	5	5	2	1	30	14.2
Constructing	1	2	5	3	7	2	4	12	36	17.0
Applying a rule Stating a rule	0	0	0	3	3	3	3	0	12	5.7
Ordering	2	1	2	3	0	0	3	0	11	5.2
Distinguishing	6	4	3	3	2	2	2	1	23	10.9
Describing	1	0	4	7	7	4	7	7	37	17.5
Identifying, Naming	17	15	7	6	1	4	4	8	62	29.4
Total	30	24	27	31	25	20	25	29	211	

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* from Science - A Process Approach Chart 1967

Action Words Within Action Words

One problem of examining the component skill statements on the Hierarchy Chart is that these behaviors are very general and are based upon a greater number of specific behavioral objectives upon which the competency measure is based. Consequently, the component skill statements encompass a greater number of action words than are represented on the Hierarchy Chart. For example, the exercise classifying 9 is based on a component skill statement that begins with "Demonstrating" but also includes behavioral objectives beginning with "state and demonstrate", "order" and "demonstrate". Other exercises provide examples of wider discrepancy between action words in component skill statements and specific behavioral objectives within the component skills.

On examining the individual activities of an exercise even more action words are encountered. Thus, in classifying 9 children "order" and "distinguish" as well as "demonstrate" illustrates the impossibility of performing any of the actions of the action words without involving some other action words. In one respect, the action word chosen to represent a component skill statement is arbitrary.

Action Words in Processes

Another question is - Do any action words occur more frequently in any of the simple processes? Table 3 shows that the most characteristic behavior of the OBSERVING process is "identifying". The CLASSIFYING process is characterized more by "constructing" behaviors. In the COMMUNICATING process, "describing" behaviors are more frequent. All this goes to show is that some processes of science, as described by AAAS, are characterized more by certain behaviors.

Table 3

Frequency of Action Words Beginning Component Skill Statements of the Eight Simple Processes

Process*	A	B	C	D	E	F	G	H
Demonstrating	3	6	7	8	4	0	0	1
Constructing	0	4	0	4	9	4	5	3
Stating a Rule	1	2	0	1	0	0	0	0
Applying a Rule	0	5	1	0	0	0	1	0
Ordering	2	0	1	4	0	0	0	1
Distinguishing	8	8	0	4	2	2	2	2
Describing	6	3	2	5	0	13	0	2
Naming	0	2	3	0	0	0	0	0
Identifying, naming	16	13	10	5	1	5	0	2
Total	36	43	23	32	16	24	8	11

* Process
Column A - Observing
Column B - Using Space/Time Relations
Column C - Using Numbers
Column D - Measuring
Column E - Classifying
Column F - Communicating
Column G - Predicting
Column H - Inferring

The action words have an additional distinction based on the human operations they seem to emphasize. Three of them are more verbal, two are more psychomotor and three can more often be characterized by mental operations although it may easily be claimed at this level that the mental operation may be a symbolic representation of a specific motor activity. It is interesting to note the frequency of occurrence of these words so classified (from table 2) "Naming and identifying" are classified together since they occur so frequently in the same statement.

Operation		Frequency
Verbal	Naming and identifying	29.4
	Describing	17.5
Motor	Constructing	17.0
	Demonstrating	14.2
Mental	Distinguishing	10.9
	Applying a rule *	5.7
	Ordering	5.2

(* includes a very small incidence of "stating a rule")

This analysis does offer some support for claiming that the general behavioral statements represented by component skills or learning sets might be arranged into a more general hierarchy dissociated from a specific content and associated only through two dimensions. One dimension is complexity. The other is logical. In a logical ordering terminal tasks require the performance of certain subordinate tasks. The terminal behavior being made up of elements of a number of subordinate skills *may* be thought of as a more complex ordering although this concept seems not as useful.

Role of Content

In this way we see it is not so much the nature of the task of "identifying" or "describing" that allows us to rank the action words into a hierarchy. Rather, it is the specific context within which the action word is being used over a limited number of learning sets. The limitation is inescapable because 1) the context of learning sets becomes increasingly more irrevelant with the increase of intervening learning sets and 2) the interdependence of learning sets becomes increasingly difficult to measure over time because of the association of "uncontrolled" experience.

This function of content as forming a fundamental basis for the association of learning sets may help to explain some dissatisfaction with a particular Process of Science such as OBSERVING. In a way, OBSERVING may be described as fundamental to all of the other seven processes in the same way that "identifying" may be fundamental to the other eight action words. The context or content of a program may be arranged to give precisely this outcome - as is illustrated by application of this model to the ESS units. The contexts used in the AAAS OBSERVING process are, however, a finite sampling from an almost infinite universe. The OBSERVING Process is only exemplary of a model which says "given adequate instruction in certain areas the learner should be able to exhibit these behaviors in slightly different contents and possession of the skills will facilitate the acquisition of subsequent ones."

Level of Describing of ESS

In the same way that learning sets or component skills are the most obvious basis or organization in each Process of the AAAS material, the list of Small Things behaviors (p.3) were based on what seemed most obvious. In both cases, as seen in the above discussion of AAAS, this is an oversimplification. In the Small Things unit, behaviors beginning with the action word "describing" may differ considerably in complexity. For example, behavior #2 (p.3) is more difficult than behavior #6. Behavior #13 could be even more complex . This situation suggests that the general hierarchy could represent many levels of complexity at the same time. In other words, arriving at level VII of the hierarchy for a relatively simple behavior may require the "cycling back" to the, beginning of the hierarchy at level I to account for the further development of a behavior. This is similiar to the kind of "phenomenological compression" discussed by Max Black in "Rules and Routines" (p.100 The Concept of Education R. S. Peters ed. The Humanities Press N.Y. 1967)

The level of complexity which we focus upon depends largely on its usefulness in attaining the objective. The objective of this paper was specifically to make an initial analysis of ESS units based on the discipline perceived in the AAAS materials. It has been shown that the level of organization here is not the only one and it is readily admitted that for other purposes a more detailed analysis may be appropriate. It is claimed however, that a more general description of behaviors as represented by the General Hierarchy would not be meaningful.

Learning Sets and Process Measure

The weakest point in this study concerns the degree to which the general behaviors of the "ESS Process Measure" may be related to the behavioral statements of a specific unit such as Small Things. The basis assumption of the process measure is that students studying Small Things will become better at certain skills measured within any context. For example:

Learning Set I. Identifying properties of an object or event. To communicate, the student must possess relevant descriptive words. In Small Things and the Process Measure he is asked to point to or name certain objects or characteristics to determine if he possesses terms prerequisite to subsequent behaviors.

Learning Set II. Describing properties of an object or event. In the Small Things unit, the student learns a "rule of describing" if the teacher follows the ESS philosophy of "pushing back."

> "...you can be continually encouraging accuracy, precision in description and observation, and refinement of other detail wherever possible."
> (p. 2 Teachers Guide for Small Things)

From studying the Small Things unit the student will more likely describe objects in a greater variety of ways and a higher proportion will meet the criteria of items 3 and 4 of the process measure in the "after" condition.

Learning Set III. Describing similarities and differences. In the Small Things unit, detailed comparison is encouraged to the same degree as describing in Learning Set II. If the student meets the criteria of Learning Set III it is highly probable that he meets those of Learning Set II. Question 5 and 6 attempted to assess the tendency to describe by use of an instrument but this would have little relation to the fact that a microscope was used or that students were at one point encouraged to describe by use of arbitrary quantitative units.

Questions 7, 8 of the process measure are directly related to the content in the first two learning sets. It was determined if the child could describe a minimum number of characteristics of geometric figures, he is then asked to compare and contrast them in a minimum number of ways. This is another rule controlled behavior which in the content of the unit was practiced by comparing cells from different parts of a plant and from different plants. However, the analysis on Chart VIII does not reflect a superior performance of the group only studying Small Things compared to ones studying both Small Things and Kitchen Physics. Any difference was very likely obscured by uncontrolled variables such as the probability that better classes studied more units.

Learning Set III was high on four measures. It had one of the highest percentages for acceptable responses for individual process measure questions (p.47). It had the largest decrease of instances inconsistent with positive transfer (chart XXIV). It had the highest value as a "mediator" of transfer (chart XIII) and it had one of the lower values of ambiguity (chart XIV).

Learning Set IV. Ordering objects or events. Questions 9 through 12 of the Process Measure assess whether the child can order the geometric objects he has previously described according to some rule.

In the unit children were encouraged to group objects according to observed characteristics. This activity became obscure when they were asked to generalize their observations in distinguishing between living and non-living.

Learning Set V. Applying a rule. Questions 13 and 14 require that the child applies two rules to identify the missing figure. One rule is a variable - the number of sides increases by one. The other rule is constant - all figures are blue.

Learning Set VI. Interpreting relationships. In question 15, the child indentifies constants and variables in terms he is familiar with - such as longer-shorter. In 16, he interprets a change or relationship in terms of a constant or variable.

Learning Set VII. Demonstration validity. In 17, the child demonstrates how he could prove his point in 16. Question 18 attempted to have the child demonstrate the application of rules learned about the ordering of geometric objects but this item resembles more closely the predicting behavior.

Chart 1

Process Measure Administered to Children Before Studying BSS Units N= 56

Question	Acceptable Responses	Percentage
1	54	96.4
2	54	96.4
3	40	71.4
4	31	55.4
5	33	58.9
6	24	42.9
7	37	66.1
8	29	51.8
9	51	91.1
10	51	91.1
11	42	75.0
12	41	73.2
13	16	28.6
14	13	23.2
15	42	75.0
16	15	26.8
17	14	25.0
18	13	23.2

Chart II

Process Measure Administered to Children After Studying ESS Units   N=101

Question	Acceptable Responses	Percentage
1	99	98.0
2	96	95.0
3	78	77.2
4	71	70.3
5	73	72.3
6	48	47.5
7	83	82.2
8	78	77.2
9	92	91.1
10	94	93.1
11	86	85.1
12	83	82.2
13	28	27.7
14	33	32.7
15	72	71.3
16	41	40.6
17	44	43.6
18	39	38.6

Chart III

Process Measure Administered to Children Before and After Studying ESS Units - Baltimore Sub Groups

	Before N=34		After N=36	
Question	Acceptable Responses	Percentage	Acceptable Responses	Percentage
1	33	97.1	35	97.2
2	33	97.1	32	88.9
3	20	58.8	33	91.7
4	18	52.9	30	83.3
5	16	47.1	29	80.6
6	10	29.4	14	38.9
7	23	67.6	34	94.4
8	24	70.6	33	91.7
9	33	97.1	35	97.2
10	32	94.1	36	100.0
11	26	76.5	31	86.1
12	19	55.9	30	83.3
13	1	2.9	5	13.9
14	1	2.9	4	11.1
15	22	64.7	32	88.9
16	1	2.9	5	13.9
17	1	2.9	13	36.1
18	1	2.9	4	11.1

Chart IV

Process Measure Administered to Children Before Studying ESS Units. Divided into upper, middle and lower third as ranked by their teachers.

	Upper Third N=18		Middle Third N=22		Lower Third N=11	
Question	Acc. Resp.	Perc.	Acc. Resp.	Perc.	Acc. Resp.	Perc.
1	17	94.4	21	95.5	11	100.0
2	16	88.9	22	100.0	11	100.0
3	15	83.3	13	59.1	7	63.6
4	11	61.1	10	45.5	5	45.5
5	14	77.8	11	50.0	6	54.5
6	12	66.7	6	27.3	2	18.2
7	14	77.8	10	45.5	8	72.7
8	12	66.7	6	27.3	6	54.5
9	18	100.0	17	77.3	11	100.0
10	18	100.0	17	77.3	11	100.0
11	16	88.9	14	63.6	7	63.6
12	15	83.3	12	54.5	9	81.8
13	7	38.9	5	22.7	3	27.3
14	5	27.8	3	13.6	3	27.3
15	14	77.8	15	68.2	8	72.7
16	6	33.3	5	22.7	4	36.4
17	6	33.3	6	27.3	2	18.2
18	5	27.8	5	22.7	2	18.2

Chart V

Process Measure Administered to Children After Studying ESS Units. Divided into upper, middle and lower third of class as ranked by their teachers.

	Upper Third N=41		Middle Third N=37		Lower Third N=23	
Question	Acc. Resp.	Perc.	Acc. Resp.	Perc.	Acc. Resp.	Perc.
1	41	100.0	36	97.3	22	95.7
2	38	92.7	36	97.3	22	95.7
3	37	90.2	31	83.8	10	43.5
4	35	85.4	31	83.8	5	21.7
5	31	75.6	27	73.0	15	65.2
6	23	56.1	16	43.2	9	39.1
7	38	92.7	30	81.1	15	65.2
8	35	85.4	30	81.1	13	56.5
9	38	92.7	36	97.3	18	78.3
10	39	95.1	35	94.6	20	87.0
11	36	87.8	32	86.5	18	78.3
12	38	92.7	29	78.4	16	69.6
13	15	36.6	8	21.6	5	21.7
14	18	43.9	12	32.4	3	13.0
15	37	90.2	20	54.1	15	65.2
16	19	46.3	14	37.8	8	34.8
17	22	53.7	15	40.5	7	30.4
18	23	56.1	10	27.0	6	26.1

Chart VI

Process Measure Administered to Children in the Fourth and Fifth Grade, Before and After Studying ESS Units

	Before N=39		After N=42	
Question	Acceptable Responses	Percentage	Acceptable Responses	Percentage
1	37	94.9	40	95.2
2	37	94.9	37	88.1
3	26	66.7	28	66.7
4	20	51.3	25	59.5
5	22	56.4	29	69.0
6	19	48.7	16	38.1
7	24	61.5	33	78.6
8	18	46.2	34	81.0
9	35	89.7	39	92.9
10	35	89.7	41	97.6
11	30	76.9	36	85.7
12	28	71.8	33	78.6
13	11	28.2	10	23.8
14	10	25.6	11	26.2
15	31	79.5	26	61.9
16	9	23.1	17	40.5
17	8	20.5	20	47.6
18	7	17.9	11	26.2

Chart VII

Process Measure Administered to Children in the Sixth Grade Before and After Studying ESS Units

	Before N=17		After N=59	
Question	Acceptable Responses	Percentage	Acceptable Responses	Percentage
1	17	100.0	59	100.0
2	17	100.0	59	100.0
3	14	82.4	50	84.7
4	11	64.7	46	78.0
5	11	64.7	44	74.6
6	5	29.4	32	54.2
7	13	76.5	50	84.7
8	11	64.7	44	74.6
9	16	94.1	53	89.8
10	16	94.1	53	89.8
11	12	70.6	50	84.7
12	13	76.5	50	84.7
13	5	29.4	18	30.5
14	3	17.6	22	37.3
15	11	64.7	46	78.0
16	6	35.3	24	40.7
17	6	35.3	24	40.7
18	6	35.3	28	47.5

Chart VIII

Acceptable Responses for after test for group doing only Small Things and group doing both Small Things and Kitchen Physics

Question	Small Things Only (N=48)		Both Units (N=35)	
	f	%	f	%
1	47	97.9	34	97.1
2	45	93.8	33	94.2
3	36	75.0	29	82.8
4	37	77.1	22	62.8
5	34	70.8	25	71.4
6	21	43.8	20	57.1
7	41	85.4	30	85.7
8	41	85.4	26	74.2
9	43	89.6	32	91.4
10	42	87.5	34	97.1
11	37	77.1	34	97.1
12	38	79.1	28	80.0
13	17	35.4	8	22.8
14	16	33.3	14	40.0
15	32	66.7	27	77.1
16	18	37.5	20	57.1
17	19	39.6	23	65.7
18	14	29.2	18	27.2

Chart IX

Percentage Difference Between Acceptable Responses for Three Groups

Question	Group Percent Differences		
	1	2	3
1	+ 1.6	+ 0.1	- 0.8
2	- 1.4	- 8.2	+ 0.4
3	+ 5.8	+32.9	+ 7.8
4	+14.9	+30.4	-14.3
5	+13.4	+33.5	+ 0.6
6	+ 4.6	+ 9.5	+13.3
7	+16.1	+26.8	+ 0.3
8	+25.4	+21.1	-11.2
9	0.0	- 0.9	+ 1.8
10	+ 2.0	+ 5.9	+ 9.6
11	+10.1	+ 9.6	+20.0
12	+ 9.0	+27.4	+ 0.9
13	- 0.9	+11.0	-12.6
14	+ 9.5	+ 8.2	+ 6.7
15	- 3.7	+24.2	+10.4
16	+25.8	+11.0	+19.6
17	+18.6	+33.2	+26.1
18	+15.4	+ 8.2	- 2.0
Total	+152.2	+293.0	+76.6

Column 1 - "After" group minus "before" group. Chart II - Chart I.
Column 2 - As above but with Baltimore subgroup. Chart III
Column 3 - Group doing both units minus group doing only one unit - Small Things. Chart VIII

Chart X

Proportion Consistent with Positive Transfer "Before" Group N=57

Summary of Pass-Fail Relationships within the General Hierarchy and the Proportion Consistent with Positive Transfer

Transfer to Learning Set	Frequency of Pass-Fail Pattern (lower to higher) (1) ++	(2) --	(3) +-	(4) -+	Total Testable Frequency 1+2+4	Proportion Consistent with Positive Transfer $\frac{1+2}{1+2+4}$
I to II B	41	0	16	0	41	1.00
II B to III	33	11	8	5	49	.90
III to IV A	38	5	0	14	57	.75
III to IV B	36	9	2	10	55	.82
IV A,B to V	19	9	28	1	29	.97
V to VI	18	11	2	26	55	.53
VI to VII	19	13	24	1	33	.97

Frequency of P-F expressed as Proportion of Total Group (57)

.72	.60	.28	.10
.58	.19	.14	.09
.67	.09	.00	.25
.63	.16	.04	.18
.33	.16	.49	.02
.32	.19	.04	.41
.33	.23	.42	.02

Chart XI

Proportion Consistent with Positive Transfer "After" Group N=101

Transfer to Learning Set	Frequency of Pass-Fail Pattern (lower to higher)				Total Testable Frequency 1+2+4	Proportion Consistent with Positive Transfer $\frac{1+2}{1+2+4}$
	(1) ++	(2) --	(3) +-	(4) -+		
I to II B	84	1	16	0	85	1.00
II B to III	81	5	3	12	98	.88
III to IV A	88	0	5	8	96	.92
III to IV B	85	2	7	7	94	.93
IV A,B to V	46	6	47	2	54	.96
V to VI	39	11	7	44	94	.53
VI to VII	54	17	27	3	74	.96

P-F frequency expressed as proportion of total group (101)

.83	.01	.16	.00
.80	.05	.03	.12
.87	.00	.05	.08
.84	.02	.07	.07
.46	.06	.47	.02
.39	.11	.07	.44
.54	.17	.27	.03

Chart XII

Mediated Transfer. Amount of Positive Transfer from Lower to Higher Learning Set with and without Successful Achievement of Intervening Learning Set. "Before" Group N=57

(1) Transfer Examined	(2) N	(3) Mediation Learning Set (M.L.S)	(4) Achieving M.L.S. +++	(5) Not Achieving M.L.S +-+	(6) Proportion (4)/(2)	(5)/(2)
I to III	57	II B	33	5	.57	.09
II B to IV A	41	III	32	6	.78	.15
II B to IV B	41	III	30	6	.73	.15
III to V	38	IV A,B	15	0	.40	00
IV A,B to VI	47	V	18	20	.38	.43
V to VII	20	VI	9	0	.45	00

(2) Number achieving Learning Set immediately subordinate to Mediation Learning Set. For example, M.L.S. III has 57 in original sample minus 16 who missed II B gives 41 - the number to be examined.

(6) Proportion successful on higher learning task when intervening learning set was achieved (4)/(2) Achieving Mediation L.S./N and not achieved (5)/(2).

Chart XIII

Mediated Transfer. "After" group N=101

(1)	(2)	(3)	(4)	(5)	(6)	
Transfer Examined	N +??	Mediation Learning Set (M.L.S)	Achieving M.L.S. + + +	Not Achieving M.L.S. + - +	Proportion	
					$4/_2$	$5/_2$
I to III	100	II B	81	11	.81	.11
II B to IV A	85	III	79	2	.93	.02
II B to IV B	85	III	77	2	.91	.02
III to V	92	IV, A,B	46	1	.50	.01
IV A,B to VI	98	V	41	35	.42	.36
V to VII	51	VI	29	2	.57	.04

Chart XIV

Proportion of Learning Sets with Ambiguious Score

(1) Learning Set	(2) Frequency of Ambiguious Score "before"	"after"	(3) Frequency of identical positive score before	after	(4) Proportion of (2) / (3) before	after	(5) Reduction of Ambiguity
I	2	5	57	94	.35	.05	+ .30
II B	11	16	41	84	.27	.19	+ .08
III	9	25	38	93	.24	.27	- .03
IV A	0	6	52	96	.00	.06	- .06
IV B	8	15	47	92	.17	.16	+ .01
V	10	30	20	46	.50	.65	- .15
VI	31	49	44	83	.70	.59	+ .11
VII	9	28	18	56	.50	.56	- .06

(2) An ambiguious score is an acceptable learning set with 1,0 or 0,1 combination.

(3) An identical score is an acceptable learning set with 1,1 combination. Unacceptable learning sets are also identical (0,0) but are not included here.

Chart XV Patterns of Learning Set Responses. Before Group N=57

teacher number		I	IIB	III	IV	V	VI	VII
5	1			-	+	-	+	-
	2					-	+	-
	3		-	+	++	-	+	-
	4		-	+	++	-	+	-
	5		-	-	++	-	+	-
	6					-	+	-
3	7							+
	8					-	+	+
	9					-	+	+
	10							+
	11					-	+	+
2	12							-
	13					-	+	-
	14							+
	15					-	+	-
	16					-	+	-
6	17					-	+	-
	18					-	-	-
	19		-	-	+-	-	-	-
	20		-	-	+-	-	-	-
	21		-	-	+-	-	+	-
	22		-	-	--	-	-	-
3	23							-
	24		-	+	++	+	-	-
	25			-	++	-	+	-
	26		-	-	++	-	-	-
	27		-	-	--	-	+	+
16	28							+
	29							+
	30							+
	31							-
	32							-
	33			-	--	-	+	-
	34			-	--	-	-	-
12	35			-	++	+	+	-
	36		-	-	++	+	+	-
	37		-	-	++	+	+	-
	38		-	-	++	-	+	-
	39				+-	-	+	-
7	40			-	++	-	-	-
	41					-	+	+
	42					-	+	-
	43							+
	44		-	+	++	-	+	+
	45				+-	-	+	+
	46					-	+	+
10	47					-	+	+
	48				++	-	-	-
	49					-	-	-
	50							-
	51			-	++	-	-	-
	52		-	+	++	-	-	-
9	53							+
	54							+
	55			-	++	-	+	-
	56			-	++	+	+	-
	57		-	-	--	+	-	-

Chart XVI Patterns of Learning Set Responses. After group N=101

x= top third of class z= lower third
y= middle third

teacher and student number		I	IIB	III	IV	V	VI	VII		no.	IIB	III	IV	V	VI	VII
5	1 z		-	-	++	-	+	-		51x						+
	2 z					-	+	-		52z						+
	3 x		-	-	++	-	-	+		53z				-	+	-
	4 y	-	-	-	++	-	+	+	10	54x						+
	5 y					-	+	+		55z				-	+	+
	6 y			-	++	-	-	-		56x						+
	7 x					-	+	+		57z	-	+	++	-	-	-
15	8 z					-	+	-		58x						+
	9 y					-	+	+		59x						+
	10 y					-	+	+		60x						+
	11 x							+	13	61x						+
	12 y							+		62y				-	-	-
19	13 x							+		63x				-	+	-
	14 y							+		64x		-	++	+	+	+
	15 y						-	-		65y				-	+	+
	16 y						-	+		66z						+
	17 z		-	+	++	+	-	+		67z	-	-	++	-	+	-
	18 z					-	+	+		68z	-	+	++	-	+	-
	19 x					-	+	-		69y				-	+	+
1	20 y					-	+	+		70x				-	+	-
	21 y					-	+	+		71y					-	-
	22 y							+		72y				-	+	-
	23 x							+		73z						+
	24 x					-	+	+	6	74z				-	-	-
	25 y							+		75y						+
	26 x							+		76y					-	-
	27 x							+		77y				-	+	-
	28 z							+		78x						+
	29 x						-	-		79y				-	+	-
	30 y							-	11	80y				-	+	-
	31 y					-	-	-		81y	-	+	+-	+	-	-
	32 x					-	+	+		82z	-	+	+-	-	+	+
	33 x							+		83y	-	+	++	-	-	-
17	34 x							+		84z						+
	35 y							+		85x				-	+	-
	36 y				--	-	+	-	8	86x						-
	37 x				-+	+	+	+		87x				-	+	-
	38 x							+		88y					-	-
	39 z		-	-	++	-	-	-		89x						-
18	40 y							-		90x						+
	41 y						-	-		91z	-	+	+-	-	+	-
	42 y			-	+-	+	+	-	14	92				-	+	+
	43 x					-	+	+		93				-	+	+
	44 y					-	+	-		94						-
	45 z		-	+	--	-	-	-		95				-	+	+
46	46 y				--	-	-	-		96	-	+	++	-	+	-
20	47 z				--	-	+	-	10	97z	-	+	++	-	+	+
	48 y					-	+	+		98y	-	+	++	-	+	+
	49 x					-	+	-		99x				-	+	-
	50 x							+		100x	-	+	++	-	+	-
										101x				-	-	-

Chart XVII

Summary of Pass-Fail Relationships Within the "ESS Behavior Hierarchy" Between Non-Adjacent Learning Sets (N=101)

Transfer to Learning Set		Frequency of Pass Fail Pattern (lower to higher)			
		(1) + +	(2) - -	(3) + 1	(4) - +
I	IIA	83	0	17	1
I	III	97	1	7	0
I	IVA	96	0	4	1
I	IVB	92	0	8	1
I	V	46	1	54	0
I	VI	81	0	19	1
I	VII	56	0	44	1
IIB	IVA	80	1	4	16
IIB	IVB	79	4	5	13
IIB	V	44	15	40	2
IIB	VI	61	7	13	10
IIB	VII	50	11	34	6
III	V	44	6	49	2
III	VI	76	3	17	5
III	VII	53	5	40	3
IVA IVB	VI	74	3	17	7
IVA IVB	VII	54	8	37	2
V	VI	53	17	28	3

Frequency of Pass-Fail Relationships (+ to -)
Listed under
Number of Intervening Learning Sets

	0	1	2	3	4	5
	1					
	5					
	1	7				
	8	5	10			
	49	49	40	54		
	9	17	17	13	19	
	17	28	37	40	34	44
Average	13	21	26	36	26	44

Chart XVIII Proportion of Acceptable Learning Sets (L.S.)*

L.S.	Before N=57	After N=101	Difference
I	1.00	.99	-.01
IIB	.72	.83	+.11
III	.65	.92	+.27
IVA	.91	.95	+.04
IVB	.82	.92	+.10
V	.35	.46	+.11
VI	.77	.80	+.03
VII	.32	.54	+.22

* from charts XV and XVI

Chart XIX Verbal I.Q. of Groups Taking Content Test

R Group	Number in Group	Number of Available Verbal I.Q's	Average Verbal I.Q.	Total Content Score*
1	114	93	108.6	387
2	65	-	-	223
3	118	114	107.5	394
4	263	63	115.0	419
5	214	146	111.0	352
6	52	42	114.0	512

* Total of seven questions from each group (Chart XX)

Chart XX

Percentage of Acceptable Responses to Content Test

		1	2	3	4	5	6
		Did Not Study ESS (5)	Seminar Teachers			Non-Seminar	
Position on Hierarchy	Quest. No.	N=114	(4) N=65	(5) N=118	(6) N=263	(5) N=214	Studied ESS Last Year(6) N=52
I	3	83.3	84.6	76.3	82.5	81.3	86.5
II	1	35.1	1.5	66.1	40.7	50.5	73.1
III	6	54.5	24.6	44.0	58.4	33.1	67.3
IV	2	22.8	7.7	19.4	31.5	28.1	40.4
V	7	76.6	41.5	89.9	76.4	70.5	88.5
VI	4	45.6	26.2	38.1	56.3	33.6	73.1
VII	5	69.3	36.9	60.2	73.8	55.5	82.7

Chart XXI Content test scores for the same subjects that took the process measure (chart XVIII) N= 59

Content test item	(1) number correct	(2) percentage	(3) Proportion of acceptable learning sets	(4) Learning Set level
1	31	53	88	II
2	21	35	97	IV
3	46	78	98	I
4	46	78	90	VI
5	41	69	63	VII
6	30	53	92	III
7	49	83	56	V

Column 2 is calculated by column 1/59 X 100

Column 3 gives the percentage of acceptable responses for learning sets for subjects taking the process measure after studying ESS units and who also took the content test (Chart XV, XVI and XXII).

Column 4 identifies the learning set level tentatively identified with the seven items of the content test

Chart XXII Profile on Content Test of After Group

Student number	Question number 1234567
1	0000100
2	0011111
3	0010001
4	0001100
5	0010010
6	0011001
7	0011111
8	0010101
9	0011001
10	0011001
11	0011101
20	0111101
21	1011101
22	1111111
23	0011101
24	0011111
25	1001111
26	0101111
27	0111101
28	1011110
29	1111011
30	0111111
31	0011111
32	0111011
33	0101011
34	1111111
35	0010110
36	1111001
37	1011111
38	1111111
40	0011001
41	1011111
42	1001101
43	1111111
44	1011111
45	0010100
46	0010101
47	0000111
49	1111111
50	1111111
51	1111101
52	1000000
53	0011000
54	0011111
55	0001111
56	0111111
57	0001000
58	1111111
59	1111011
60	0111111
74	1011101
75	1010101
76	1010001
77	1011101
78	1011011
79	1011101
80	0010101
82	0010111
84	1111011
85	0011111
86	1011000
87	1001101
88	1011101
89	1101111
91	1001111

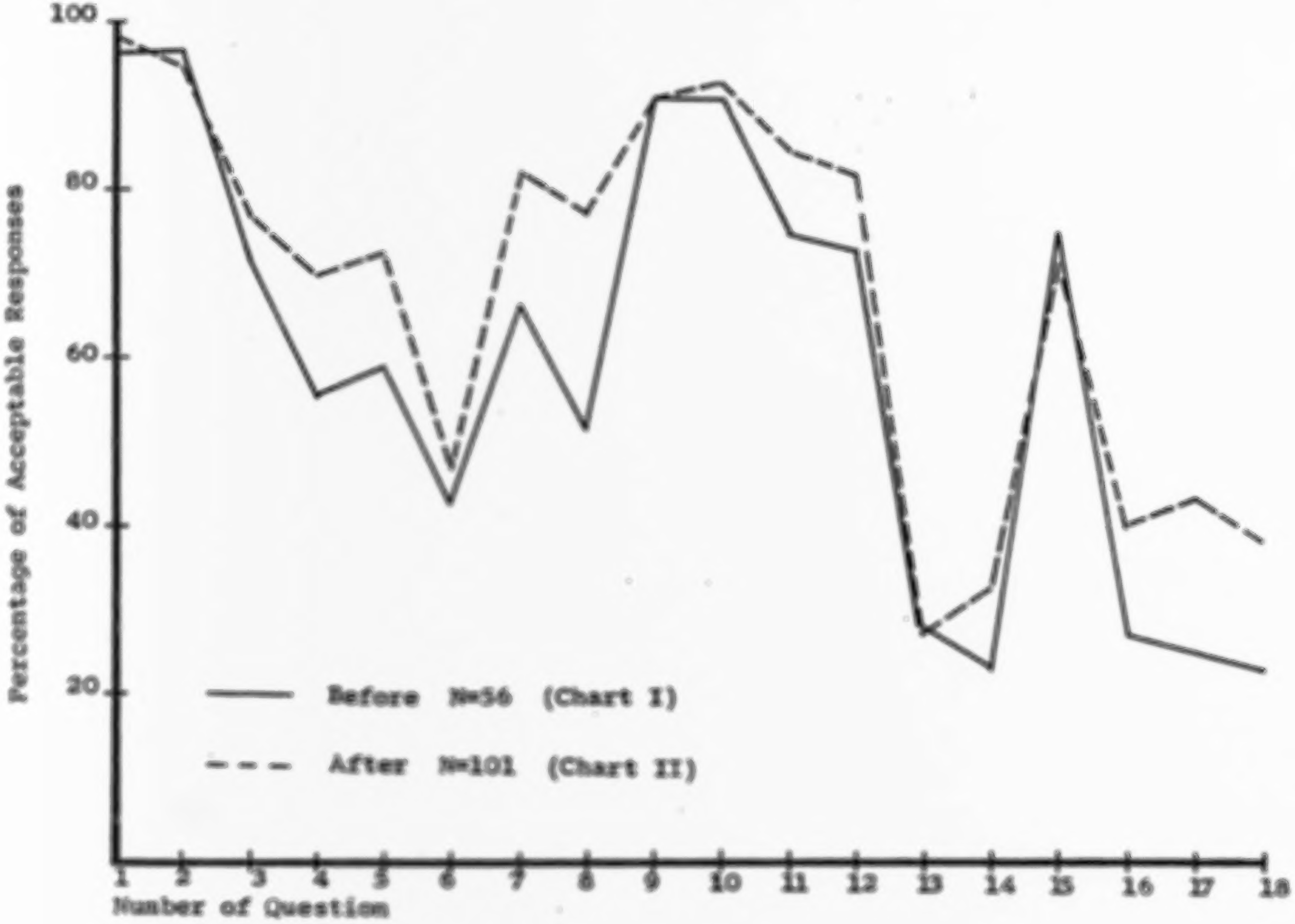
student numbers refer to chart XVI
1 means question was answered
"satisfactorily" (page 53)
0 means is was not satisfactory

Chart XXIII Number Correct for Content test and Process Measure

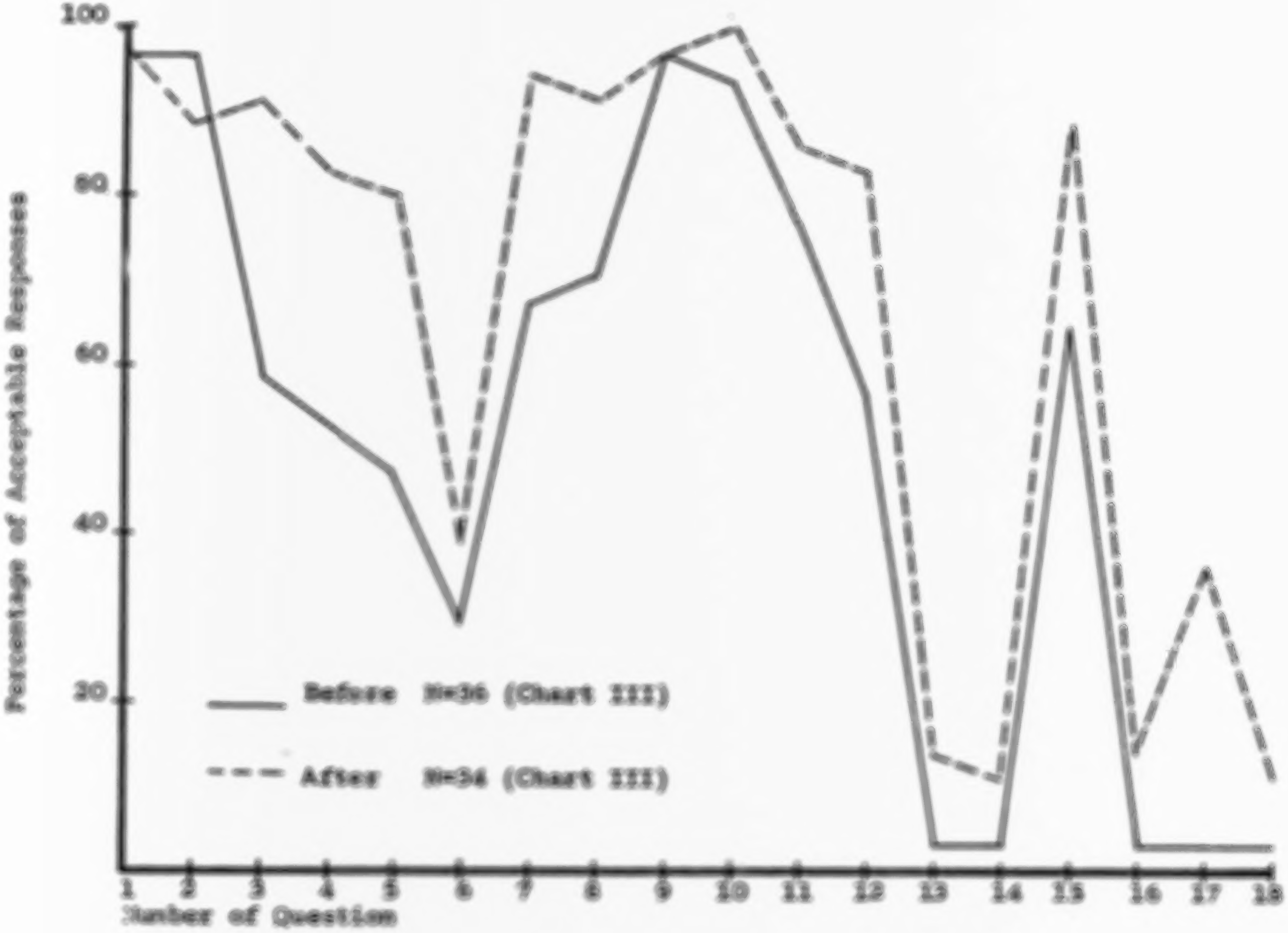
lower third		middle third		upper third	
N=14		N=20		N=25	
content	process	content	process	content	process
1	4	2	1	2	4
1	4	2	4	3	6
1	8	3	3	4	8
2	1	3	4	4	8
2	8	3	6	4	8
3	4	3	6	5	6
3	6	3	7	5	7
4	5	3	7	5	7
4	7	3	7	5	7
5	4	3	8	5	8
5	5	4	5	5	8
5	6	4	8	5	8
5	8	5	4	6	6
6	8	5	5	6	7
		5	6	6	8
		5	6	6	8
		5	6	6	8
		5	7	6	8
		5	7	7	6
		55	8	7	7
				7	8
				7	8
				7	8
				7	8
				7	8
$\overline{3.3}$	$\overline{5.6}$	$\overline{3.8}$	$\overline{5.8}$	$\overline{5.4}$	$\overline{7.3}$

This chart is calculated from chart XVI and XXII. The above items represent the number of correct responses on the content test compared to the number of correct responses on the process measure for each individual taking both tests.

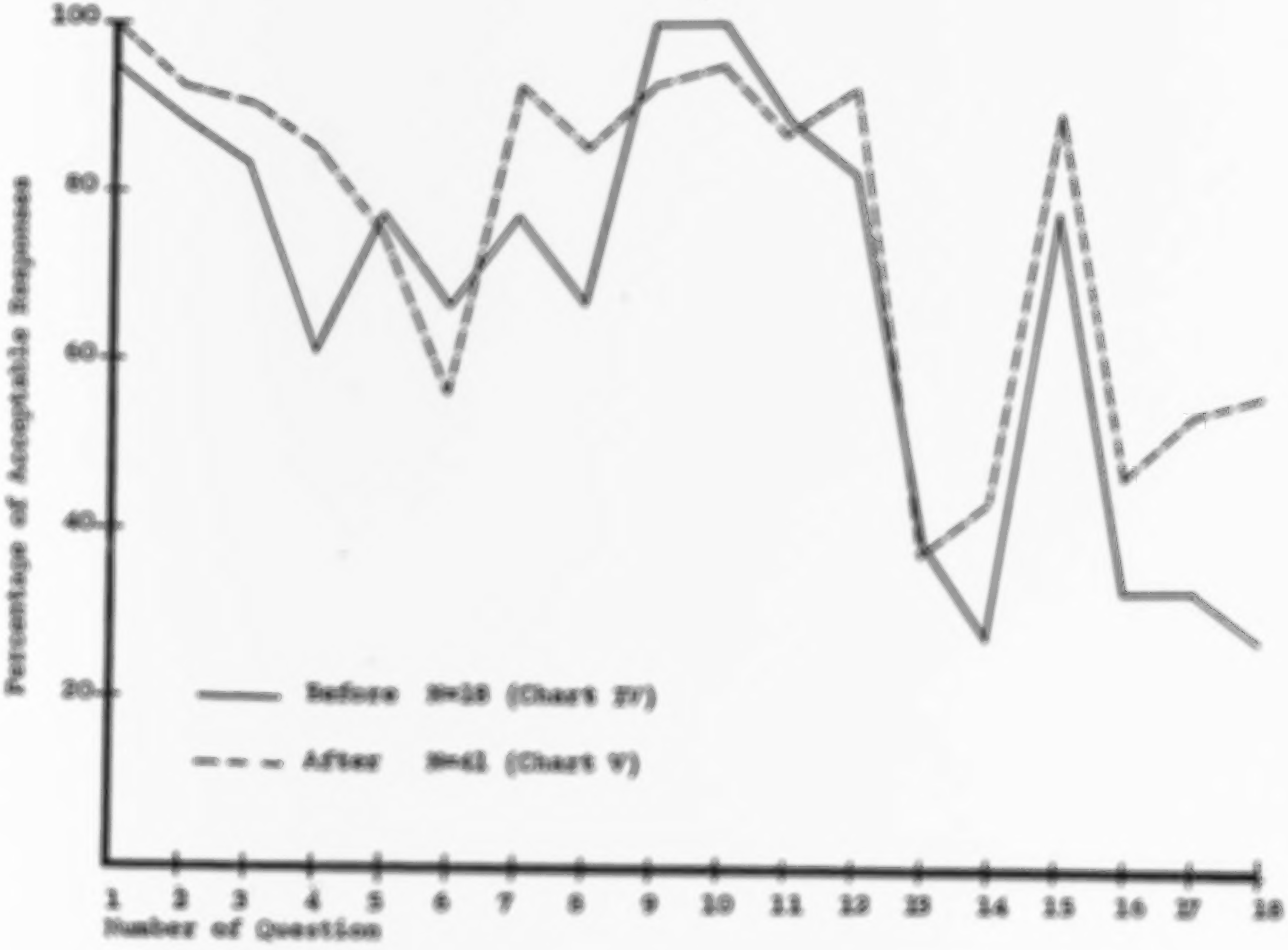
Graph I Process Measure Before and After ESS Units



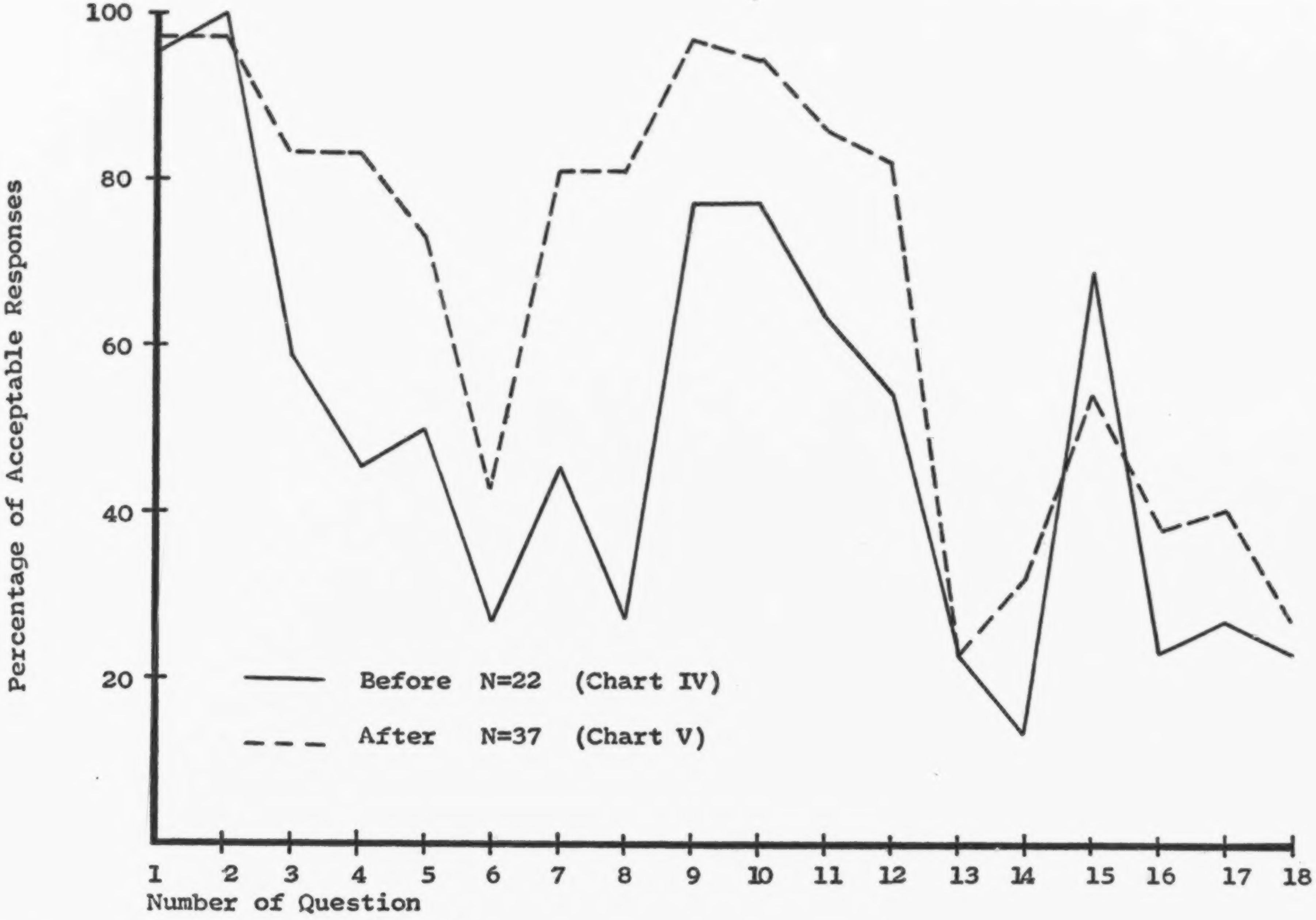
Graph II   Baltimore Sub Group   Before and After ESS Units



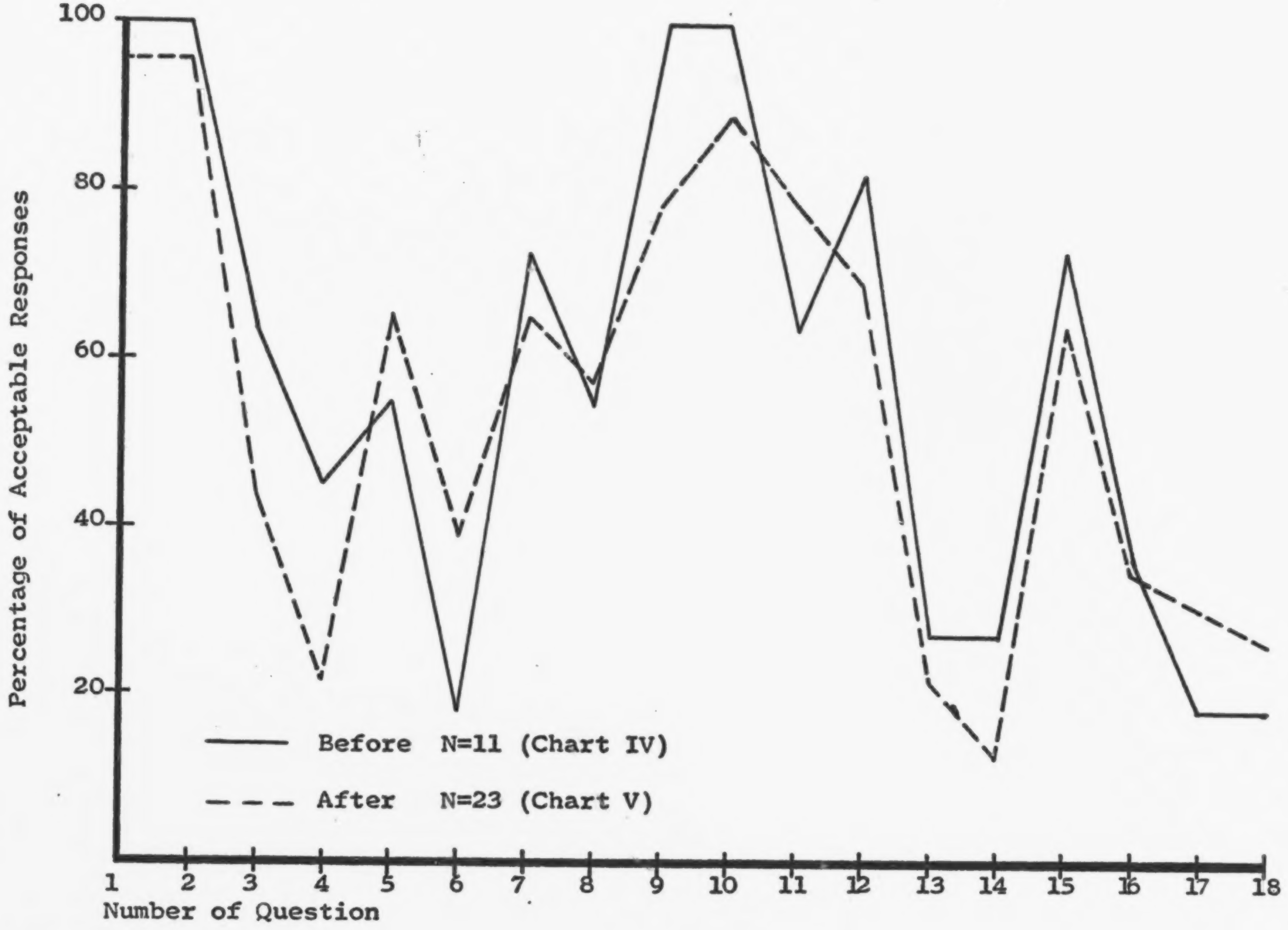
Graph III Process Measure Before and After ESS Units
Upper "Third" of Class



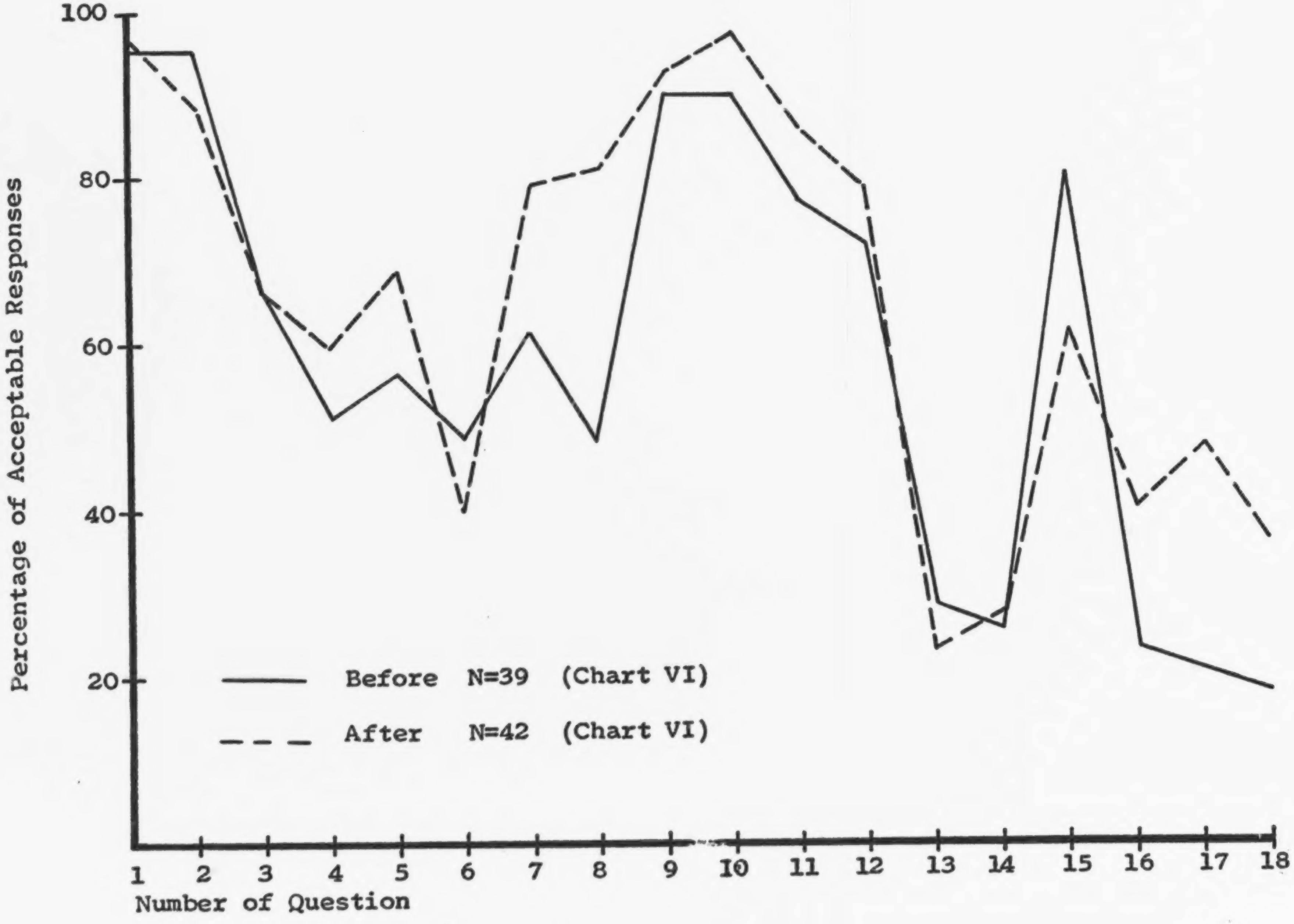
Graph IV Process Measure Before and After ESS Units
Middle "Third" of Class



Graph V Process Measure Before and After ESS Units
Lower "Third" of Class



Graph VI Process Measure Before and After ESS Units
Fourth and Fifth Grades Combined



Graph VII Process Measure Before and After ESS Units
Sixth Grade